THE FUSE SURVEY OF O VI ABSORPTION IN AND NEAR THE GALAXY

B.P. Wakker[1], B.D. Savage[1], K.R. Sembach[2], P. Richter[1,3], M. Meade[1], E.B. Jenkins[4], J.M. Shull[5], T.B. Ake[6,7], W.P. Blair[6], W.V. Dixon[6], S.D. Friedman[6], J.C. Green[8], R.F. Green[9], J.W. Kruk[6], H.W. Moos[6], E.M. Murphy[10], W.R. Oegerle[6], D.J. Sahnow[6], G. Sonneborn[11], E. Wilkinson[5], D.G. York[12]

ABSTRACT

[1]Department of Astronomy, University of Wisconsin, 475 N Charter St, Madison, WI 53706

[2]Space Telescope Science Institute, 3700 San Martin Drive, Baltimore, MD 21218

[3]Osservatorio Astrofisico di Arcetri, I-50125, Firenze, Italy

[4]Department of Astrophysical Sciences, Princeton University, Princeton, NJ 08544

[5]Center of Astrophysics and Space Astronomy, University of Colorado, Boulder, CO 80309

[6]Department of Physics and Astronomy, Johns Hopkins University, Baltimore, MD 21218

[7]Science Programs, Computer Sciences Corporation, Lanham-Seabrook, MD 20706

[8]Center for Astrophysics and Space Astronomy, Department of Astrophysical and Planetary Sciences, University of Colorado, Campus Box 389, Boulder, CO 80309

[9]National Optical Astronomy Observatories, P.O. Box 26732, Tucson, AZ 85726

[10]Department of Astronomy, University of Virginia, P.O. Box 3818, Charlottesville, VA 22903

[11]Laboratory for Astronomy and Solar Physics,, NASA Goddard Space Flight Center, Code 681, Greenbelt, MD 20771

[12]Department of Astronomy and Astrophysics, University of Chicago, 5640 South Ellis Av., Chicago, IL 60637

We present *Far Ultraviolet Spectroscopic Explorer* (*FUSE*) observations of the O VI $\lambda\lambda$1031.926, 1037.617 absorption lines associated with gas in and near the Milky Way, as detected in the spectra of a sample of 100 extragalactic targets and 2 distant halo stars. We combine data from several *FUSE* Science Team programs with guest observer data that were public before 2002 May 1. The sightlines cover most of the sky above galactic latitude $|b|>25°$ – at lower latitude the ultraviolet extinction is usually too large for extragalactic observations. We describe the details of the calibration, alignment in velocity, continuum fitting, and manner in which several contaminants were removed – Galactic H_2, absorption intrinsic to the background target and intergalactic Lyβ lines. This decontamination was done very carefully, and in several sightlines very subtle problems were found. We searched for O VI absorption in the velocity range -1200 to 1200 km s^{-1}. With a few exceptions, we only find O VI in the velocity range -400 to 400 km s^{-1}; the exceptions may be intergalactic O VI. In this paper we analyze the O VI associated with the Milky Way (and possibly with the Local Group). We discuss the separation of the observed O VI absorption into components associated with the Milky Way halo and componet at high-velocity, which are probably located in the neighborhood of the Milky Way. We describe the measurements of equivalent width and column density, and we analyze the different contributions to the errors. We conclude that low-velocity Galactic O VI absorption occurs along all sightlines – the few non-detections only occur in noisy spectra. We further show that high-velocity O VI is very common, having equivalent width >65 mÅ in 50% of the sightlines and equivalent width >30 mÅ in 70% of the high-quality sightlines. The high-velocity O VI absorption has velocities relative to the LSR of $\pm$(100–330) km s^{-1}; there is no correlation between velocity and absorption strength. We discuss the possibilities for studying O VI absorption associated with Local Group galaxies, and conclude that O VI is probably detected in M 31 and M 33. We limit the extent of an O VI halo around M 33 to be <100 kpc (at a 3σ detection limit of log N(O VI)$\sim$14.0). Using the measured column densities, we present 50 km s^{-1} wide O VI channel maps. These show evidence for the imprint of Galactic rotation. They also highlight two known H I high-velocity clouds (complex C and the Magellanic Stream). The channel maps further show that O VI at velocities <-200 km s^{-1} occurs along all sightlines in the region l=20°–150°, $b<-30°$, while O VI at velocities >200 km s^{-1} occurs along all sightlines in the region l=180°–300°, b>20°.

Subject headings: ISM: structure, Galaxy: halo, ultraviolet: ISM

1. INTRODUCTION

The *Far Ultraviolet Spectroscopic Explorer* (*FUSE*) provides high resolution spectra in the wavelength regime between 905 and 1187 Å, making it one of the few observatories (past or present) that allows observations shortward of 1150 Å down to the Galactic Lyman edge. This spectral region contains the resonance absorption lines of the most abundant atoms and molecules including, for example, H I, H_2, O I, O VI, C II, C III, Fe II and Fe III. Interstellar absorption line observations with *FUSE* enable studies of all phases of the interstellar gas, including the cold neutral and molecular medium, the warm neutral medium, the warm ionized medium and the hot ionized medium. *FUSE* was launched in June 1999. The capabilities of *FUSE* are described in detail by Moos et al. (2000) and Sahnow et al. (2000).

FUSE data consist of 8 separate ∼90 Å wide spectra, identified as LiF1A, LiF1B, LiF2A, LiF2B, SiC1A, SiC1B, SiC2A and SiC2B. The LiF1A, LiF2B, SiC1A and SiC2B spectra cover the region near 1030 Å, which allows the study of absorption by five-times ionized oxygen (O^{+5}), a good diagnostic of gas at temperatures near 3×10^5 K. This ion has a high enough ionization potential (113.9 eV is required to convert O^{+4} to O^{+5}) that it is not produced by photoionization caused by extreme ultraviolet radiation from normal stars, which is suppressed above energies of 54.4 eV because of the strong He^+ absorption edge in the stellar atmosphere. O^{+5} has two strong resonance absorption lines at 1031.9261 Å and 1037.6167 Å, with oscillator strengths of 0.133 and 0.066 (Morton 1991).

FUSE is the first instrument with sufficient sensitivity *and* spectral resolution to observe O VI absorption using large numbers of extragalactic objects as background targets. The *FUSE* Science Team designed a number of programs to systematically map the distribution and amount of Galactic O VI. Several programs concentrate on the Galactic disk, while others emphasize the Galactic halo. The halo program is divided into two parts – a study of the vertical distribution of the O VI using a set of stars located at different heights above the Galactic plane, and a study of the integrated column density using a sample of extragalactic targets. This paper describes the basic target information, the technical details of the data handling, and derived parameters for the extragalactic study.

We present a catalog and some general analyses of this dataset, with an emphasis on discriminating the different phenomena that are present. Detailed interpretations, with more emphasis on a physical understanding, are presented by Savage et al. (2002) and Sembach et al. (2002b). The former paper analyzes the O VI absorption that is clearly associated with the Milky Way, which we also refer to as the "thick disk" O VI. It discusses in depth the angular and spatial distributions, the kinematics, the relation of O VI to other components of the Galaxy and the implications for understanding the Galaxy as a whole. As we find in this catalog paper, high-velocity O VI absorption is present along many sightlines. This turns out to sample varied phenomena, some of which may not be directly associated with the Milky Way. The physical interpretation of this aspect of the O VI sky is discussed in detail by Sembach et al. (2002b).

This paper is constructed as follows. First, we discuss the manner in which the sample of extragalactic objects was assembled (Sect. 2). Table 1 lists the object and observation information. In Sect. 3 we first summarize the reduction steps (Sect. 3.1) and then describe the calibration (Sect. 3.2), the absolute alignment and relative alignment between different spectrograph segments (Sects. 3.3 and 3.4) and finally how different observations and segments were combined (Sect. 3.5). Next we describe how the continuum was fit (Sect. 3.6), how the final binning was determined

(Sect. 3.7), and how contamination by Galactic molecular hydrogen (H_2), intrinsic AGN lines, and intergalactic absorption was removed (Sects. 3.8–3.10). Section 4 details the process of measuring the O VI lines. First, a velocity range of integration is determined (Sect. 4.1), then we measure the equivalent width and study the distribution of the statistical and systematic errors in the equivalent width (Sect. 4.2). Next we discuss the column densities and compare the values derived from the O VI λ1031.926 and O VI λ1037.617 lines to determine whether saturation could be important (Sect. 4.3). Scientific results are presented in Sect. 5 – the detection rate for Galactic and high-velocity O VI (Sects. 5.1–5.3), a check on the possibilities for detecting O VI absorption from other Local Group galaxies using our sample (Sect. 5.4) and O VI channel maps (Sect. 5.5). Finally, we add an Appendix, in which notes are presented concerning each sightline.

2. OBJECT SELECTION

2.1. Observing Program Summary

FUSE Science Team targets were chosen through a process that involved considerations of expected flux and sky coverage. For most objects in programs P101, P107, P108 and P207, the selection process was similar. First we searched the *HST* and *IUE* archives for ultraviolet observations of extragalactic sources. Typically, this involved checking low dispersion *IUE* data or Faint Object Spectrograph (*FOS*) data. We fitted a power law continuum to all objects with detectable flux, making sure to avoid obvious stellar absorption features and emission lines. This fit was typically performed in the 1200–1600 Å spectral region. Once the fit was performed, we extrapolated the continuum fit to shorter wavelengths and estimated a continuum flux at 1000 Å. Differential extinction was not taken into account, but most sightlines are at high latitude and thus have E(B−V)<0.07 (see Table 1). The predicted fluxes are compared with the observed values in Sect. 3.6.2.

We then constructed a catalog of the 200 objects having the highest 1000 Å fluxes. The cutoff at the low flux end was typically 10^{-14} erg cm^{-2} s^{-1} Å^{-1}. The brightest targets were then selected for inclusion in the main O VI halo survey of extragalactic objects (28 objects in programs P101 and P108, as well as two objects observed during the commissioning phase; programs X017 and I904). When choosing from among these objects, we tried to choose diverse locations on the sky as well as to select objects for which high quality *HST* observations of C IV and N V were already available for comparison with the O VI. Many of the remaining objects were chosen for short snapshots in the D/H program to search for extragalactic Lyman-limit systems (37 objects in program P107). Since early operations with *FUSE* had to be performed with limited maneuvering, the intended 2 ks snapshots were often extended to 10 ks or longer. Thus, the data quality of the P107 snapshot program observations was often higher than originally anticipated.

We excluded most known Seyfert 2 AGNs from the halo and D/H surveys since these objects tend to have strong absorption features due to the stellar populations of the host galaxies. Thus, most of the objects in the sample in these programs are either quasars or type 1 Seyferts.

In the second cycle of *FUSE* observing, 29 objects were included in the P207 snapshot program based on their optical and X-ray fluxes as derived from the ROSAT point source catalog. These objects had no previously known ultraviolet data and were of unknown source type, although most were expected to be QSOs. Eleven were found to have sufficient flux to be included in the final sample.

For five six *FUSE* Science Team programs that were geared toward observations of Galactic O VI (P101, P107, P108, X017, I904), a total of 3267 ks of exposure time was obtained for 70 objects, of which 3042 ks resulted in useful spectra for 57 objects. The remaining 225 ks were not suitable for our analysis because either the object was too faint (7 objects), had a Lyman limit system covering the O VI lines (3C 351.0), had H_2 or IGM lines covering the O VI lines (4 objects, see Sects. 3.8 and 3.9), or was mispointed (IRAS F07546+3928). For six objects some observations were not used because much longer observations were available.

Several other Science Team programs had different goals (e.g., measuring D/H or intrinsic absorption in AGNs), but also produced spectra useful for measuring Galactic O VI (P110, P111, P190, P191, P198, P207, Q105, Q106, Q223 and Q224). A total of 1817 ks of exposure time for 58 objects was obtained for these programs, of which 466 ks for 24 objects resulted in spectra useful for our program. Of the 1351 ks that we do not use, 886 ks was useful for other purposes, while 465 ks were spent on 30 objects that turned out to be too faint to be useful.

In addition to the objects observed as part of the *FUSE* Science Team effort described above, we decided to include public data from the *FUSE* guest observer program. The rationale for this was twofold. First, many of these observations were not taken for the purpose of studying Galactic O VI, but usually for the purpose of studying either the intergalactic medium or the AGN being observed. Further, by including these objects, we expanded our sample considerably, especially in some regions of the sky where the Science Team program had only sparse coverage. We checked all guest observer datasets that became public before 1 May 2002. Of these 96 sources (1749 ks total exposure time), 57 were too faint and 12 had a continuum that was too complicated in the 1030 Å region to allow a measurement of Galactic O VI absorption. Two objects (Mrk 153 and PG 1011-040) yielded good spectra, but were excluded from our sample because the Guest Observer's science aims overlapped ours. The remaining 25 objects (555 ks total exposure time) were included in the sample. These are objects from programs A023 (PI Buat), A035 (PI Mulchaey), A036/B022 (PI Thuan), A046 (PI Heckman), A060 (PI Koratkar), A068 (PI Bregman), A086 (PI Keel), A088 (PI Brown), A121 (PI Gibson), B062 (PI Mathur) and B087 (PI Prochaska). We thank these investigators for their permission to use their data.

Since there are 5 objects that are in more than one of the categories listed above, the final sample consists of 290 observations of 219 objects observed for a total of 6834 ks (1898 hours or 79.0 days). A spectrum with sufficiently high S/N ratio and reliable information for our study of Galactic O VI was obtained for 102 objects (100 extragalactic and 2 distant halo stars, excluding Mrk 153 and PG 1011−040), amounting to 4214 ks (1171 hours or 48.7 days) of exposure time.

All objects that were part of the P, Q, X and I series of programs were calibrated by us (see Sect. 3.2 below for details). Guest Observer data were first retrieved from the "Multi-Mission Archive at Space Telescope" (*MAST*) archive at the *STScI* (Space Telescope Science Institute), which provides reasonably-well calibrated datasets. If the observation was deemed possibly useful, we calibrated it more carefully, using the same procedure as for the Science Team data, described in Sect. 3.2 below.

2.2. Object Data

Table 1 gives object and observation information for all objects in our sample. We checked the basic data in *NED*, the *NASA-IPAC Extragalactic Database; http://nedwww.ipac.caltech.edu.* Using our preferred names (see below) in a *NED* search will yield information for the object. We discuss some objects with troublesome names below, so that the reader can find these also.

Column 1 of Table 1 gives the object name. This is usually, but not always, the same name as was used in the *FUSE* observation log. Many objects have multiple names. Column 16 of Table 1 lists the alternative “Mrk”, “PG”, “Ton”, “UGC” or Zwicky name for the object, if it exists. We established the following order of preference for the prefix indicating the source catalogue: “NGC”, “3C”, “Mrk”, “PG”, “Ton”. This led us to prefer Mrk 116 over I Zw 18, Mrk 771 over PG 1229+024, Mrk 1095 over Akn 120, Mrk 1502 over I Zw 1, Mrk 1513 over II Zw 136, PG 0844+349 over Ton 951 and PG 1302−102 over PKS 1302−102. We further used the full name as specified in *NED* for some objects for which an abbreviated 12-character version was used in the *FUSE* observation log. This left 10 cases where we found that the name used in the *FUSE* observation log was highly irregular. We then used *NED* to find an alternative name. For 7 of these the choice was easy, as other sources with the same prefix are present in the sample. In two cases both the original name and the alternative name were possibilities. We chose PHL 1811 over FIRST J2155−0922, Tol 1924−416 over IRAS 19245−4140 and UGC 12163 over Akn 564, since these preferred names are more indicative that the object is a blue galaxy.

Four objects had some name complications. First, both the *FUSE* observation log and *NED* give PG 1114+445 instead of PG 1114+444. The B1950 declination of PG 1114+444 is $+44^\circ29'56''$, and the IAU naming convention calls for cutting, not rounding the coordinates. Second, in the original PG catalogue, the right ascension of PG 1544+489 is given as $15^h44^m00^s$, whereas a more precise determination gives $15^h43^m59.93^s$. Since the IAU rule is that a name should be based on the original catalogue, this implies that the name PG 1543+489 used in *NED* is in error. Third, the object named QSO 0045+3926 in the *FUSE* observation log is only recognized by *NED* as IO And, S 10785 or RX J0048.3+3941; we used the last of these. Finally, we note that *NED* stores HS 1102+3441 under the name PG 1102+347, even though the PG catalogue lists no object at this position.

The J2000 equatorial coordinates of the objects are given in Cols. 2 and 3 of Table 1, with galactic longitude and latitude in Cols. 4 and 5. For most objects these were found from the Véron-Cetty & Véron (2000) catalogue of QSOs and Seyferts. Thirty-five objects (including thirteen elliptical galaxies and 5 H II regions) are not present in that catalogue, so we used the coordinates given in *NED*.

We used the *NED* database to find the velocity or redshift for each object. Column 6 gives the object's radial velocity, if it is <6000 km s^{-1}, or the redshift, if it is >0.02. The object HS 1549+1919 is unknown within either *NED* or *SIMBAD*, and its redshift is unknown. For RX J0042.0+3641 and RX J1306.3+3917 *NED* does not provide a redshift. In three cases (PG 0804+761, PG 1211+143, PHL 1811) the redshift in *NED* is incorrect, and an updated value is provided (see the notes in Appendix A).

Column 7 of Table 1 gives the classification, also from *NED*. This can be one of the following: "QSO" or "BLLac" (for quasars), "Sey#" (where a number between 1 and 2 gives the numerical subclassification), "Gal:*mmm*" (with *mmm* the morphological classification), 'Gal:HII" (for the three Tololo objects, which are galaxies whose light is dominated by H II regions), "'BCG" (Blue Compact Galaxy), "BCD" (Blue Compact Dwarf), "StrBrst" (a starburst galaxy), "HII(*ggg*)" (for Mrk 59, NGC 588, NGC 592 and NGC 5461, which are bright H II regions inside another galaxy, whose name is given by *ggg*), "sdO" (for PG 0832+675 and vZ 1128). Note that for QSOs *NED* gives "QSO" on its summary line, but in the body of the information each QSO is classified as either "Sey1", "Opt.var." or (in a few cases) "E2" or "E4". We use the "QSO" classification in these cases.

In Col. 8 the blue magnitude of the object is given, taken from the catalogue of Véron-Cetty & Véron (2000). *NED* gives a preferred magnitude, but does not specify for which band it is; B magnitudes are not always given either. Column 9 shows the value of the reddening that *NED* gives for the direction to the target. These are based on the *IRAS/DIRBE* measurements of diffuse infra-red emission (Schlegel et al. 1998), but may not be free of systematic errors (see explanations in *NED*).

Columns 10–13 give the basic *FUSE* observation information – the year, month and day of the observation, the identification code of the *FUSE* observing program, the observation ID within that program and the nominal exposure time. The observation ID has two parts – a target ID within the observing program and a visit number. Within each observation there are a varying number of single orbit exposures. For a few observations the information is preceded by "[" and followed by "]". These are observations that were not used in the final combined spectrum for the object (see Sect. 3.4). Except for the observation of NGC 5253 all spectra were taken through the LWRS aperture.

The nominal exposure time given in Col. 13 is the time that the observation log specifies. However, parts of the observation are often lost because of "event bursts" or other problems (see Sect. 3.2), and the usable time is less than the nominal time; this can differ for the different spectrograph segments. We also decided not to use the SiC data due to the higher noise in that channel. Therefore, Cols. 14 and 15 give the useful on-object time for both the LiF1A and the LiF2B segments. In a few early observations there is no signal in the LiF2B segment, as indicated by the dash in Col. 15 (3C 249.1, Fairall 9, Mrk 352, Mrk 817, NGC 985, PG 0052+251, PG 1302−102, PKS 2155−304, Ton S180, Ton S210). For many faint guest observer sources, we did not run the *FUSE* pipeline again (described in Sect. 3.2), but instead just used the *MAST* data, in which bursts have not been removed. This is indicated by ellipses in the table.

3. DATA PREPARATION

3.1. Summary of Steps

In this section we discuss the steps necessary to create a final spectrum in the region around the O VI absorption lines. The resulting spectra are shown in Fig. 1. Their construction is described in Sects. 3.2 to 3.10.

The top panel of Fig. 1 presents a wide wavelength range centered on 1032 Å, showing the general behavior of the continuum. For this and the other panels, the vertical scale gives the absolute flux in units of 10^{-14} erg cm^{-2} s^{-1} Å^{-1}. The top level is set to 1.4 times the flux level at 1032 Å, with a minimum value of 2.8×10^{-14} erg cm^{-2} s^{-1} Å^{-1}. The strong line near 1025.722 Å is Galactic Lyβ absorption, in the center of which geocoronal Lyβ emission is always seen. Geocoronal O I and O I* emission may also be present, at 1027.431, 1028.157, 1039.230, 1040.942 and 1041.688 Å. Several interstellar lines are always seen in the 1015–1050 Å wavelength range, these are the slightly broad features at 1020.699 Å (Si II), 1026.476 Å (O I), 1036.337 Å (C II), 1037.018 Å (C II*), 1039.230 Å (O I) and 1048.220 Å (Ar I). In addition many H_2 lines fall in this wavelength range (3 with J=0, 5 with J=1, 5 with J=2, 6 with J=3 and 7 with J=4). These show up as very narrow lines.

The second panel presents the O VI λ1031.926 absorption line, on the calibrated LSR velocity scale (see Sect. 3.4). The positions of nearby H_2 lines are indicated by the labels P3 and R4. The line showing the continuum includes the expected H_2 lines, whose parameters were determined in the manner described in Sect. 3.8. H_2 wavelengths and oscillator strengths were taken from Abgrall & Roueff (1989) and Abgrall et al. (1993a, 1993b). If a feature has been identified with intergalactic absorption or if absorption is associated with the background object (see Sect. 3.9), this is indicated by the label. For features that may be Lyβ, but which are not positively identified, a "?" is added. If the possible Lyβ is not confirmed, but very likely exists because of the presence of a galaxy group in the sightline, a ":" is added. The small bar in the lower left corner shows the $\pm1\sigma$ noise level (at 10-pixel binning, i.e., per 20 km s^{-1} resolution element). The thick vertical bars connected to the top axis show the velocity ranges over which the O VI λ1031.926 line was integrated to derive equivalent widths and column densities (see Sect. 4.1).

The third panel shows the O VI λ1037.617 line. There are several other absorption lines near this line, which are indicated by the labels C II and C II* for the C II λ1036.337 and C II* λ1037.018 lines, and R0, R1, P1 and R2 for the four H_2 lines at 1036.546, 1037.146, 1038.156 and 1038.690 Å, respectively. The continuum is also shown in this panel, except for a few sightlines where the continuum fit near 1037 Å is too uncertain.

The fourth panel contains the apparent column density profile for both O VI lines (see Sect. 4.3). The thick line is for the O VI λ1031.926 line, the thin one for O VI λ1037.617. The latter was shifted to positive velocities by 10 km s^{-1} to correct for an apparent discrepancy in the wavelength calibration present in v1.8.7 of the *FUSE* pipeline (see Sect. 3.4 for a description of the apparent column density and the justification for the shift). Note that we used the nominal shift for the O VI λ1037.617 absorption profile in the panel above. The labels identify the other absorption lines near both O VI lines. The profile for the O VI λ1037.617 line is cut off below a velocity of -110 km s^{-1} and above a velocity of 280 km s^{-1} in order to avoid clutter associated with the C II, C II* and H_2 lines. This panel is omitted for the objects for which the spectrum was too noisy or the O VI line was not measureable for other reasons.

The fifth, sixth and seventh panels from the top present the low-ionization absorption lines (C II λ1036.337, Si II λ1020.699 and Ar I λ1048.220) that were used to align the *FUSE* spectrum with the H I emission data (see Sect. 3.4). These lines also serve as a guide for showing the properties of strong, medium and weak low-ionization species in neutral and weakly-ionized gas.

The bottom two panels show the H I spectrum (see Sect. 3.3) – first with a vertical scale emphasizing the brightest component, then with a vertical scale emphasizing the low-intensity higher-velocity components. The label in the top left corner gives the telescope used to obtain the H I spectrum – "LDS" means the Leiden-Dwingeloo Survey, "VE" means Villa Elisa, "GB" means the Green Bank 140-ft, "Pks" means Parkes and "Eff" means the Effelsberg telescope, See Sect. 3.3 for more details. The bottom of the figure lists the parameters of a gaussian decomposition of the H I spectrum. Five numbers are given. First a component identification, next the central velocity in $\mathrm{km\,s^{-1}}$, then the amplitude, A, of the gaussian in K, the FWHM, Γ, of the line in $\mathrm{km\,s^{-1}}$, and the H I column density, in units of 10^{18} cm^{-2}. N(H I) is calculated as $\sqrt{\pi/4\ln 2}\;A\;\Gamma\times 1.82{\times}10^{18}$.

Table 2 summarizes the derived parameters for each object. In this table the objects are sorted by object name, divided into two groups. The first group contains all the objects for which the measured signal-to-noise ratio per resolution element is >3 (see Sect. 3.7), toward which we can measure the Galactic O VI column density. The remaining, fainter, objects follow.

Below, we summarize the contents of the columns of Table 2, but we refer to later sections for the detailed descriptions of the meaning of the specified values.

Column 1 of the table gives the object name (see Sect. 2.2).

Column 2 gives the number of LiF1A and LiF2B segments used to construct the final spectrum (see Sect. 3.5). For objects where the LiF2B segment was not used a preceding "f" indicates that the reason is that there is no recorded flux in the segment, while a "d" indicates that the LiF1A and LiF2B segments disagree. For spectra with high S/N ratio (>14) only LiF1A was used.

Column 3 gives the "effective exposure time". This is the total exposure time in the LiF1A segment plus half that in the LiF2B segment (if it was used), after removing bursts (see Sect. 2.2). The LiF2B channel is weighted half as much as the LiF1A channel since it produces half the number of counts for the same exposure time. Some values are given within parentheses. These are for guest observer objects that we did not recalibrate because either the continuum is too complicated to measure Galactic O VI, or because the source is too faint.

Columns 4–9 give the flux, the rms noise, the signal-to-noise (S/N) ratio in a 10-pixel bin (corresponding to 20 $\mathrm{km\,s^{-1}}$, or one resolution element), the signal-to-noise ratio at the final rebinning, the final rebinning near the O VI line, and a "quality factor"; see Sect. 3.7 for details.

Columns 10 and 11 describe the continuum fit (see Sect. 3.6).

Column 12 summarizes the intergalactic absorption (see Sect. 3.10). Columns 13 and 14 list the galaxy groups that the sightline intersects, as determined using the catalogues of Geller & Huchra (1983, 1984) and Tully (1988).

Columns 15 and 16 give the highest rotational level of H_2 that is detected, and whether the

H_2 lines contaminate the O VI λ1031.926 absorption (see Sect. 3.8).

Columns 17–23 give the LSR velocity range and equivalent width of the Milky Way and HVC O VI absorption (see Sect. 4.1). The "x"-es and the "[,]" pairs before or after the minimum or maximum velocity of integration (Cols. 17/21 and 18/22) indicate sightlines with a difficult separation between Milky Way and high-velocity O VI (see Sect. 4.1 for the full description. In Col. 20 a classification is given for the high-velocity O VI component. The corresponding phenomena are summarized in Sect. 5.5. Sembach et al. (2002b) present a full discussion.

3.2. Calibration

A general description of the *FUSE* mission and its characteristics was given by Moos et al. (2000) and Sahnow et al. (2000). *FUSE* consists of four aligned telescopes and spectrographs, two of which have an Al+LiF coating to produce spectra between 1000 and 1187 Å, and two of which have a SiC surface optimized for the 905–1105 Å wavelength range. There are two detectors, one for each LiF/SiC channel pair, called Side 1 and 2, which are composed of two microchannel plates, called segment A and B. The segments are separated by a 10 Å gap and the detectors are aligned such that most wavelengths are covered at least twice.

Since all our objects produce low data rates, all observations were done in the "time-tag" mode, in which the (x,y) address of each photon is saved, with a time tag inserted once a second. One such photon list is produced for each segment for each orbital visibility period, during which on the order of 2000 seconds of data are taken. Most observations take longer than a single orbit, so the first step in our procedure is to use the program "ttag_combine" (v1.0.4) to combine all of the raw data of the different one-orbit exposures into a single photon list.

For a few sightlines of special interest (PG 1259+593, NGC 1705, and NGC 3310) a slightly more elaborate procedure was applied: all individual exposures were separately processed and Doppler-corrected before combining. For long observations (>30 ks) of bright objects (flux $>3\times10^{-14}$ erg cm^{-2} s^{-1} Å^{-1}) it should in general be possible to align the data for each individual orbit, and combine the aligned exposures. As the pointing may vary slightly from orbit to orbit this can in principle improve the resolution of the data. For three objects (Mrk 153, Mrk 279 and Mrk 817) we compared the spectra obtained using this method with those obtained from the standard "ttag_combine". Indeed, narrow lines such as Ar I λ1048.220 become slightly narrower (by 1–2 km s^{-1}), but the difference is small. We conclude that in general it is not necessary to apply an exposure-by-exposure alignment when the goal is to measure the broad O VI lines.

A complication of *FUSE* data is that they contain intermittent increases in the count rate (see Sahnow et al. 2000). The duration of these "bursts" is between a few and several hundred seconds. They are still unexplained. Since the bursts are isolated in time, they can easily be removed. We used the IDL utility "fuse_scan" that is provided by the *FUSE* software group to identify and remove the bursts by hand, separately for each segment.

Next we ran the *FUSE* calibration pipeline. We used version 1.8.7, which was available from the *FUSE* web site at the Johns Hopkins University as of November 2000. This process does the following: a) it screens out the times that the satellite passed through the South Atlantic Anomaly (SAA), and times that it pointed near the Earth limb; b) it corrects for detector drift and geometric distortions on the detector; c) it corrects for satellite motion and grating rotation during the observation; d) it subtracts the background; e) it applies a wavelength calibration; f) it converts the counts to a flux, taking into account dead time. No flat fielding or astigmatism correction is applied; see Moos et al. (2000) and Sahnow et al. (2000) for discussions of these effects on the data. The background correction that is applied is based on assuming a uniform rate of 1 count $\mathrm{cm^{-2}\,s^{-1}}$ across the detector, and ignores the scattered light differences between observations during orbital day and night. This implies that there may be slight offsets for long integrations.

A newer version (v2.0.5) of the pipeline software became available as we were finishing the data handling. We did a few comparisons between the two versions and decided not to recalibrate the data, as the largest difference is in the wavelength calibration, and we already addressed this difference (see Sect. 3.4). If one retrieves calibrated data from the *MAST* archive at the Space Telescope Science Institute, most of these calibration steps are also done, except that bursts (and, in a few cases, bad exposures) are not removed. This adds noise to the spectra, and also implies that the flux calibration may be in error because the on-source exposure time is no longer the nominal exposure time.

The *FUSE* pipeline was applied separately to each of the 8 segments. We ran this process twice, once for all data, and once selecting only the data that were taken during orbital night. In the latter dataset airglow lines are much fainter. The airglow lines that lie closest to the O VI lines are those of Lyβ at 1025.722 Å and O I and O I* at 1027.431, 1028.157, 1039.230, 1040.942 and 1041.688 Å. These do not overlap the O VI lines, and for the current study we therefore used the combined orbital day and night data.

For two objects (Ton S210 and HE 0226−4110), an earlier short observation was followed by a second, longer observation, which was taken using a "focal-plane split" (i.e., the spectrum was deliberately shifted on the detector from orbit to orbit in order to reduce the effects of fixed-pattern noise in the combined spectrum). As the *FUSE* pipeline assumes that the detector position stays constant from exposure to exposure within a multi-orbit observation, we ran the pipeline separately for each of the 15 (for Ton S210) or 19 (for HE 0226−4110) orbits and combined the data later.

After running the pipeline, we were left with one file for each detector segment, each covering about 90 Å, with a pixel spacing of about 0.0068 Å, or about 2 $\mathrm{km\,s^{-1}}$. Not all these detector pixels are independent, however. The properties of the optics and the detector combine so that a photon at a given wavelength may produce signal in any one of about 3–4 (near 1030 Å) or even 5–6 (near segment edges) adjacent detector pixels. We therefore always binned the data over at least 5 pixels. For fainter sources we created larger bins.

We note that *FUSE* produces a very low background signal. For long integrations this usually remains below $\sim 2\times10^{-15}$ $\mathrm{erg\,cm^{-2}\,s^{-1}\,Å^{-1}}$, and it should have been corrected for by the calibration software. We checked this in each spectrum by examining the flux level in the C II λ1036.337 line. This line is always strongly saturated over the wavelength range where $N(\mathrm{H\ I})>10^{18}$ $\mathrm{cm^{-2}}$ and the flux in the center of the line should be zero. There were just two objects for which this was not true: HE 0226−4110 and Mrk 771. These discrepancies may reflect non-uniformities in the intrinsic or scattered-light components of the background. Since these are not precisely known, we did not apply a correction.

3.3. H I Spectra

In order to better interpret and measure the absorption spectra, and in order to properly align the different segments, we collected an H I 21-cm spectrum for each of our objects. For objects with declination $>-35°$, we first extracted a spectrum from the Leiden-Dwingeloo Survey (LDS, Hartmann & Burton 1997); the Dwingeloo telescope has a $35'$ beam. For 97 objects only LDS data were available. For the 16 objects with more southern declinations we requested a spectrum from the survey by Arnal et al. (2000), which was done using the Villa Elisa telescope ($34'$ beam).

It has been shown previously that the smaller the beam the better the approximation to the H I column density in the pencil-beam toward a background source (e.g., Wakker & Schwarz 1991, Wakker et al. 2001, 2002). Therefore, whenever possible, we also used data from several other telescopes with smaller beams. For 22 objects, we have Effelsberg data available; the Effelsberg telescope has a beam of $9\overset{'}{.}7$. These spectra were taken in the same runs as were described by Wakker et al. (2001), and are mostly for objects projected on known H I high-velocity clouds. For one object (Fairall 9), a Parkes ($16'$ beam) spectrum was available, courtesy Gibson et al. (2001). For 80 objects we took the spectra from Murphy et al. (1996), who used the Green Bank 140-ft Telescope ($21'$ beam) to measure accurate H I spectra in the direction of 220 QSOs and AGNs. The Green Bank spectra also are more sensitive and have a better baseline subtraction than the LDS data.

All H I spectra have a velocity resolution of $\sim$1 km s^{-1}, and all spectra were corrected for stray-radiation. For the objects where we have data from more than one radio telescope available, we cross-checked the component structure to see whether or not weak components were present in both spectra. The H I spectrum with the smallest beam is included in Fig. 1, as is the result of a gaussian fit to the H I components; the telescope is indicated by a label (LDS, VE, GB, Pks, or Eff). See also the description in Sect. 3.1.

3.4. Alignment in Velocity

The spectra that come out of the *FUSE* calibration pipeline are nominally calibrated in wavelength. However, in practice there are offsets between segments and the absolute wavelength scale is usually slightly offset. This problem was particularly severe before February 2001, at which time an improved wavelength calibration algorithm was provided by the *FUSE* software group although this was not included in our version of the calibration pipeline and needed to be applied later. Also, in v1.8.7 of the pipeline there was a sign error in the heliocentric to LSR conversion. Furthermore, we discovered that at first we did not use the proper orbital parameter file (we did not recalibrate these spectra). All these problems resulted in minor distortions of the wavelength scale (20 km s^{-1} over 50 Å), but mostly in large unpredictable shifts (up to 100 km s^{-1}). After we finished determining the channel alignments, version 2.0.5 of the *FUSE* calibration pipeline became available. This version has an improved wavelength calibration, except that minor offsets (up to 50 $\mathrm{km\,s^{-1}}$) in the absolute alignment of the wavelength scale still occur.

Our calibrations were complete before v2.0.5 became available. We knew about the problems with the wavelength scale, so we therefore determined the zero-point of the wavelength scale in the region around the O VI $\lambda\lambda$1031.926, 1037.617 doublet from the data, rather than from using the wavelength calibration. This was done by aligning the Si II λ1020.699 and Ar I λ1048.220 lines with the H I-21 cm emission observed in the direction of the extragalactic object. Below, we first discuss the rationale for using Ar I λ1048.220 and Si II λ1020.699 (point 1). Next we discuss our treatment of the H I spectrum (point 2), followed by some comments on the resulting alignments (point 3). Then we comment on differences between the velocity scales of the two versions of the calibration pipeline (point 4), followed by a discussion of the intrinsic difficulty of aligning absorption and emission lines originating in different kinds of gas (point 5). Finally, we summarize the sources of alignment errors and present a conclusion on the accuracy of the alignment (point 6).

1) Rationale for using Ar I λ1048.220 and Si II λ1020.699. We used the Ar I λ1048.220 and Si II λ1020.699 lines since a) they lie on opposite sides of the O VI λ1031.926 line and b) the H I column density usually is on the order of a few 10^{20} $\mathrm{cm^{-2}}$, in which case these lines are strong but usually not highly saturated, so that the position of the deepest absorption usually corresponds to the strongest H I component. For a few sightlines we also checked several of the H_2 lines between 1028 and 1043 Å, but these were only used to confirm the alignment, as it is not a-priori clear with which H I component they correspond. For sightlines with low FUV flux we further checked the C II λ1036.337 line, and demanded that the full extent of the H I profile fell within the region where C II λ1036.337 is saturated.

2) The H I spectrum. To find the alignment, we first fitted a set of gaussians to each H I spectrum, in the manner described by Wakker et al. (2001). We then noted the velocity of the strongest component. In the majority of cases (185 out of 219) this velocity lies within about 15 $\mathrm{km\,s^{-1}}$ from v_{LSR}=0 $\mathrm{km\,s^{-1}}$. A small positive offset (v_{LSR}=19 $\mathrm{km\,s^{-1}}$) is seen toward NGC 1705. In 31 directions lying in the area of sky containing the Intermediate-Velocity Arch and Spur (see Wakker 2001), the strongest component in the H I profile lies at a velocity between −60 and −15 $\mathrm{km\,s^{-1}}$. Finally, toward PG 1259+593 HVC complex C at v_{LSR}=−128 $\mathrm{km\,s^{-1}}$ is the strongest H I component. These cases clearly show that blindly assuming that the peak of the H I is located near 0 $\mathrm{km\,s^{-1}}$ might lead to an erroneous velocity scale.

For 32 sightlines no single H I component dominates the spectrum, and instead there are two (or even three) components of similar strength. In this case the interstellar absorption lines may be broad, or if the different components have different element depletions due to the presence of dust, one absorption component may be stronger, although it would not be a-priori clear which one. Some of these objects have very low FUV flux and the alignment cannot be adequately determined. In other sightlines we checked the individual absorption features carefully to determine the most likely alignment.

3) Results. To do the alignment, two of us (Wakker/Richter) independently determined the apparent velocity of the Ar I λ1048.220 and Si II λ1020.699 lines in the LiF1A segment and visually estimated the shift necessary to align these lines with the H I. Subsequently, we overlaid the LiF2B spectrum and determined its shift relative to that of LiF1A for the same observation by visually aligning them as well as possible. In almost all cases this gives an unambiguous result for the differential alignment, accurate to about 3–5 km s^{-1} at high S/N ratios, and to about 10–15 km s^{-1} at low S/N ratios.

In most cases, the shifts implied by the Ar I λ1048.220 and Si II λ1020.699 lines appeared to be nearly the same, although in a few cases they differed by up to 20 km s^{-1}. Such ambiguities often made it necessary to simply adopt an average shift. In a limited number of cases we later compared our shifts with those implied by v2.0.5 of the pipeline. This showed that there may be a systematic difference of 15 km s^{-1} between the two lines (see point 4 below). We did not revisit the velocity alignment for all 119 sightlines after we found this out. Also, because the Ar I λ1048.220 and Si II λ1020.699 lines differ in shape, and because we had not noted down for each individual sightline whether we gave the highest weight to Ar I λ1048.220 or to Si II λ1020.699, we concluded that we could not correct for this systematic difference by applying a blanket average shift of 8 km s^{-1}.

The final shifts we determined for the LiF1A segment from the v1.8.7 calibrations have a bi-modal distribution: there is a peak at -85 km s^{-1} with an rms of 14 km s^{-1}, and another at -8 km s^{-1} with an rms of 19 km s^{-1}. These shifts may be due to a misalignment between the LiF1A channel and the Fine Error Sensor (the camera that determines the pointing). This should not happen, but an analysis by Bowen & Jenkins (priv. comm.) suggests that it does. For our project this does not matter because we align the spectra with the H I data a-posteriori. Of more interest is the difference in the shift between the LiF1A and LiF2B segments. We find that this difference has a gaussian distribution with an average value of v(LiF1A)$-v$(LiF2B)$=-18$ km s^{-1} and a dispersion of 18 km s^{-1}, showing that even after applying the proper wavelength calibration one should still carefully check the alignment between the different segments.

4. Comparison between v1.8.7 and v2.0.5. For six high signal-to-noise objects (3C273.0, H 1821+633, Mrk 153, Mrk 335, Mrk 509 and vZ 1128), we also ran v2.0.5 of the pipeline and compared the positions of several absorption lines. This shows that it is still necessary to introduce a data-based shift in the velocities in order to align the absorption with the H I. However, these shifts are smaller than for v1.8.7. If we align the O VI λ1031.926 lines produced by v1.8.7 and v2.0.5 of the pipeline, there appears to be a systematic change in the relative position of the other absorption lines. For the H_2 line at 1008.553 Å v(v1.8.7)$=v$(v2.0.5)-10 km s^{-1}; for the S III λ1012 line the difference is -5 km s^{-1}, for Si II λ1020.699 it is 0 km s^{-1}, for C II λ1036.337, O VI λ1037.617, O I λ1039.230 it is -10 km s^{-1}, for Ar I λ1048.220 it is -15 km s^{-1}, for Fe II λ1063.176 it is -25 km s^{-1}, and for H_2 λ1077.138 it is -30 km s^{-1}.

However, the implied velocities of the center of the absorption in each of these lines may still differ; for 3C273.0, Mrk 153 and vZ 1128 the velocities of the deepest absorption in the Ar I λ1048.220 and Si II λ1020.699 lines agree better in the v1.8.7 calibration; for H 1821+643, Mrk 335, Mrk 509 they agree better in v2.0.5. This effect may be due to intrinsic differences in the absorption lines (see point 5 below), or it may be due to residual errors in the wavelength calibration. In any case, there is still some uncertainty in the absolute velocity of the different lines.

We note that we also checked the data used to actually define the wavelength calibration for v2.0.5. These data are measurements of the raw pixel positions of many lines in several spectra with very high signal-to-noise ratios. Distortions of up to 20 $\mathrm{km\,s^{-1}}$ are removed by fitting the average line positions, but the residuals still have a dispersion of 5 $\mathrm{km\,s^{-1}}$.

The systematic wiggle in the wavelength scale of v1.8.7 is particularly important for comparing the two O VI absorption lines. Even before v2.0.5 was available, we had already noticed that the O VI λ1037.617 line seemed systematically shifted by -10 $\mathrm{km\,s^{-1}}$ relative to the O VI λ1031.926 line. This is very obvious in some sightlines (e.g., vZ 1128 and 3C 273.0, see Sembach et al. 2001b). Figure 2 presents four sightlines that illustrate this effect. On the left hand side we show apparent column density ($N_a(v)$) profiles (see Sect. 4.3 for the definition), using the nominal wavelength scale produced by the v1.8.7 pipeline, while on the right hand side a $+10$ $\mathrm{km\,s^{-1}}$ shift for the O VI λ1037.617 line is included. For each of the four sources the two $N_a(v)$ profiles are shown in the top panel, while the ratio of the two is shown in the bottom panel. For vZ 1128 the shift is clearly visible in the profiles, unlike what is the case for the other three sightlines. For these one needs to look at the ratio plot, which is clearly much flatter after the correction is applied, in the velocity range defined by the heavy vertical lines on the $N_a(v)$ plot. The conclusion we draw from this comparison is that the wavelength scale used in v1.8.7 of the calibration pipeline has a systematic offset of 10 $\mathrm{km\,s^{-1}}$ between the two O VI lines.

5. Intrinsic difficulties with aligning absorption lines with H I. We note that even if the H I profile shows a sharp peak, the absorption lines do not necessarily peak at exactly the same velocity since the H I spectrum measures the average emission over a $10'$, $21'$ or $36'$ beam, within which there may be velocity gradients. The absorption, however, is seen on the pencil-beam toward the background source. This is illustrated by the complications found for the sightline toward 3C 273.0 (Sembach et al. 2001b). They found that in the $21'$ Green Bank 140-ft beam the H I shows peaks at -6 and 23 $\mathrm{km\,s^{-1}}$, while the S II absorption seen with the *GHRS* on *HST* centers at -15 and 23 $\mathrm{km\,s^{-1}}$, although there is an extra, narrow, feature at -6 $\mathrm{km\,s^{-1}}$. Arguing that there could be ionization differences between the different ions in the 23 $\mathrm{km\,s^{-1}}$ positive-velocity gas, they align the two features seen in the Ar I λ1048.220, Si II λ1020.699 and Fe II λ1063.176 Å lines with the smoothed S II spectrum, resulting in velocities of -15 and 18 $\mathrm{km\,s^{-1}}$ for S II. The H_2 absorption would then be at 16 $\mathrm{km\,s^{-1}}$. However, an argument could be made that the ionization differences occur in the gas near 0 $\mathrm{km\,s^{-1}}$ and that the Ar I λ1048.220 and H_2 absorption should align with the 23 $\mathrm{km\,s^{-1}}$ H I component. Using v2.0.5 of the pipeline clarifies some of these issues, especially since the resolution seems slightly better. If we align the H_2 absorption with the 23 $\mathrm{km\,s^{-1}}$ component, then a second weak H_2 absorption component lies at -14 $\mathrm{km\,s^{-1}}$, the Ar I λ1048.220 line centers at -15 and 16 $\mathrm{km\,s^{-1}}$, the Si II λ1020.699 line at -16 and 11 $\mathrm{km\,s^{-1}}$, and the Fe II λ1063.176 line at -14 and 10 $\mathrm{km\,s^{-1}}$. These differences in alignment between different versions of the pipeline and between different ions illustrate the difficulty of aligning the complex wide-beam H I spectrum with the complex pencil-beam absorption spectra.

6. Summary of alignment errors. In summary, there are many sources of error in determining the alignment of the *FUSE* spectra. The internal accuracy of the wavelength scale is about 5 $\mathrm{km\,s^{-1}}$, as determined by the fit to many lines in some spectra with high signal-to-noise ratios. For v2.0.5 the relative alignment between different absorption lines seems correct to within this error, but for v1.8.7 there may be a systematic stretch of 15 $\mathrm{km\,s^{-1}}$ between Ar I λ1048.220 and Si II λ1020.699. Since we did not correct for this stretch, on average there may be an offset of $\sim$8 $\mathrm{km\,s^{-1}}$ in out final alignments. For many sightlines the H I spectrum has a well defined peak that can be aligned with either Ar I λ1048.220 or Si II λ1020.699 to within one rebinned pixel (5 $\mathrm{km\,s^{-1}}$ in spectra with high S/N ratio, 10 $\mathrm{km\,s^{-1}}$ at low S/N ratio, see Sect. 3.6). In some cases, the H I peak is broad and the alignment becomes more uncertain. However, the alignment between the peak of the H I emission and the peak absorption may differ by 10 $\mathrm{km\,s^{-1}}$ (as illustrated by the 3C 273.0 sightline). Also, the gas observed in H I, Ar I and Si II λ1020.699 may sample different parts of interstellar space under different physical conditions. Taking into account all these effects we conclude that for spectra with high signal-to-noise ratios our alignments are accurate to within 15 $\mathrm{km\,s^{-1}}$ for 80% of the sightlines (corresponding to a 1-σ error of $\sim$10 $\mathrm{km\,s^{-1}}$, but that in some cases a future study may show that our alignment is in error by as much as 25 $\mathrm{km\,s^{-1}}$.

3.5. Combining Segments

For the O VI doublet, the most sensitive data are obtained from the LiF1A segment (which covers 987–1082 Å), while the LiF2B segment (978–1074 Å) yields a spectrum with a S/N that is $\sim$1.4 times lower. The SiC1A segment (1004–1091 Å) and SiC2B segment (1016–1105 Å) also cover the O VI lines, but these data are much noisier, and we did not use them. The resolution in the LiF1A segment is on the order of 20 $\mathrm{km\,s^{-1}}$ (0.070 Å), while that in the LiF2B segment is slightly worse.

Since the LiF1A segment has a better S/N ratio and resolution than the LiF2B segment, we prefer to use it. In fact, for objects with sufficiently high S/N ratio (see Sect. 3.7), combining the two segments would actually lead to a reduction in the quality of the spectrum because of the lower resolution and the uncertainties in aligning different channels. In these cases we still used the LiF2B segment as a check on the features in the spectrum, and in all cases we found that within the errors the two segments give the same answers for quantities like the equivalent width. For objects with a very low S/N ratio (see Sect. 3.7) we deemed it too difficult to determine the alignment between the two segments, so we also used just the LiF1A segment. For objects with intermediate S/N ratios we decided to combine the LiF1A and LiF2B segments. Then the factor $\sqrt{1.5}$ increase in the S/N ratio more than offsets the problems associated with combining two segments which have slightly different resolutions.

To combine the spectra we used the count arrays provided by the *FUSE* pipeline. Using the flux arrays we reconstructed the conversion from count to flux for each segment. The LiF1A pixels were then shifted appropriately. Next, the LiF2B counts and conversion factors were shifted, regridded to the LiF1A wavelength grid and added to the LiF1A data. The final counts were then converted back to flux. A similar procedure is used when combining multiple observations.

For a number of sightlines more than one observation was obtained, on different dates. These were also combined, after applying the shifts, which were determined separately for each observation. In a few cases (ESO 265−G23, Mrk 79, Mrk 618, Mrk 817, Mrk 1095, VII Zw 118) one of the 2 or 3 observations had a much shorter integration time than the other(s). We then decided that adding the extra counts did not compensate for the uncertainties in determining the proper alignment for data with low S/N.

For most of the sightlines the spectrum in the LiF1A segment is nearly identical to that in the LiF2B segment, within the noise. However, there are cases where this is not so. For 3C249.1, HE 0450−2958, IRAS09149−6206, Mrk 59, Mrk 357, NGC 595 and Ton S210 the differences are fairly sutble and certainly within the noise. For HS 0624+6907, Mrk 106, Mrk 618, PG 1415+451 and Tol 1924−416, the differences are quite easily noticeable, but since these spectra have low S/N ratios, it can still be argued that the differences lie within the noise. Since the weight of the LiF2B segment is half that of the LiF1A segment, we still combined the LiF1A and LiF2B segments. For MRC 2251−178, NGC 5548, PG 1001+291 and PG 1211+143, however, the difference is particularly striking, and we decided that we should discard the LiF2B segment.

Another kind of problem occurs for 6 bright objects for which multiple observations are available (Mrk 279, Mrk 509, Mrk 817, PG 0804+761, PG 0953+414, PKS 2155−304). For these the calibrated flux differs between the different observations, by up to a factor two, although the spectra have the same shape and show the same features. For the early observations of Mrk 509 and PKS 2155−304 (prior to November 1999), the LiF1A and LiF2B fluxes also disagree, but this might be explained by misalignments in the telescope/slit or mirror/detector systems. However, since for the other objects the LiF1A and LiF2B segments in a single observation do agree, it is likely that the differences in flux between different observations are due to intrinsic variations in the extragalactic sources.

3.6. Continuum Fitting

3.6.1. Fitting Procedure

After combining different segments, the resulting spectrum was considered to be the final one. The next step was to fit a continuum. To do this, we first selected two or more narrow (a few Å) wavelength regions in the wavelength range between 1020 and 1050 Å. The selected regions lie away from known Galactic absorption lines and are visually free of other redshifted lines. We then fitted a Legendre polynomial to the selected regions, using the algorithm described by Sembach & Savage (1992). This method also provides an estimate for the error in the placement of the continuum for each pixel.

The fit described above provides a global continuum. It is the fit shown in Fig. 1. If the fits only made sense in part of this range, only that part is displayed. However, such a fit is not appropriate for determining the error in the equivalent width and column density associated with the continuum placement, as for this purpose the continuum near O VI λ1031.926 should not be constrained by what happens 20 Å away. Therefore, we also fitted a local continuum, between 1029 and 1035 Å, using the global continuum as a guide, and making sure that at the O VI λ1031.926 line the local continuum level differs by $<0.5\sigma$ from the global level. This local fit usually can be accomplished using a lower polynomial order. However, it produces substantially larger (and more realistic) continuum placement errors.

The orders of both the global and local polynomials are listed in Col. 10 of Table 2. In those cases where a local fit was not possible because the continuum had too much curvature, or there were interfering features, no separate local fit was done. This is indicated by having an "x" as the order of the local continuum fit. We also assigned a one-word description of the shape of the continuum to each spectrum (Col. 11). We further noted the continuum flux level at the center of the O VI λ1031.926 line. This is given in Col. 4 of Table 2. For objects where the O VI λ1031.926 line sits in the wing of Lyβ absorption associated with the background object, or where the spectrum shows large fluctuations, this number is lower than the continuum flux elsewhere in the spectrum. Then the continuum value over most of the spectrum is also given in Table 2, in Col. 11, between square brackets, after the word describing the continuum shape.

3.6.2. Continuum Characteristics

As described in Sect. 2.1, *IUE* spectra were used to estimate the FUV flux for all AGNs observed by that satellite in order to define a sample of objects for the *FUSE* Science Team Projects. Figure 3 shows the comparison of the extrapolated flux and the flux actually observed at 1030 Å, for the 72 observed objects with predicted flux $>2\times10^{-14}$ erg cm^{-2} s^{-1} Å^{-1}. The correlation coefficient of this collection of points is just 0.69. The ratio averages to 1.09 with a dispersion of 0.81. For 75% of the objects the prediction is correct to within a factor of 2, for 10% the ratio observed/predicted is >2, and for 15% it is <0.5. Clearly, a source that is bright at $\lambda>1200$ Å will generally be bright at 1030 Å, but the actual flux remains uncertain. This uncertainty is of similar magnitude for galaxies, Seyferts and quasars, and it is independent of the shape of the continuum. Some of the difference between observed and predicted flux may be due to intrinsic variability.

Not all AGNs that *FUSE* might observe were already observed by *IUE*. To allow an estimate of the flux at 1030 Å (F(1030)) for any AGN, we therefore also compared the visual and blue magnitude from the Véron-Cetty & Véron catalogue of AGNs with the observed flux – visual magnitudes are available in this catalogue for 151 targets, blue magnitudes for 83. Figure 4 shows the results of this comparison. Panels a) and b) show that for QSOs there is a fairly good correlation between magnitude and F(1030) (correlation coefficient ~-0.75). This correlation does not depend on the reddening; correcting for the reddening does not change it substantially, as the corrections are generally small. The faintest objects for which the flux level can be somewhat reliably determined have F(1030)$\sim5\times10^{-15}$ cm^{-2}. Including just objects brighter than this, the correlation coefficient is also ~-0.75. Almost all QSOs with B$<$15 have F$>10^{-14}$ erg cm^{-2} s^{-1} Å^{-1} at 1030 Å, while those with B$>$16.5 are too faint to observe with *FUSE*. On the other hand, the correlation for Seyferts (panels c and d) is poor (correlation coefficient ~-0.45). For nearby galaxies with V$<$12 (panel

e) the correlation is bad. However, these galaxies usually are larger than the *FUSE* aperture, and thus the visual/blue magnitude refers to a different part of the galaxy than the *FUSE* observation. For the smaller (fainter) galaxies (V>12), the correlation coefficient is ∼−0.6 (panels e and f).

The shape of the continuum is characterized as "Flat", and fit by a straight line (polynomial order 1) for 60 objects with flux $>4.5\times10^{-15}$ erg cm^{-2} s^{-1} Å^{-1} (and for one fainter one with a long observation, KUG 1031+398). Usually the slope of the polynomial is ∼0. For 58 objects with flux $<4.5\times10^{-15}$ erg cm^{-2} s^{-1} Å^{-1} we list a shape of "Zero" in Table 2, as there really is not enough flux to determine the continuum shape. In 31 cases the Galactic O VI sits in the damping wing of Lyβ absorption associated with the background galaxy. The continuum shape then is listed as "Lyβ[#]", where the # gives the average flux over most of the spectrum. In these cases the line-free regions selected to make the polynomial fit only cover the spectrum to the side of the wing nearest to O VI λ1031.926.

For the remaining 66 objects the continuum shows varying degrees of curvature. The least troublesome are the 16 we loosely classify as "Curved", in which case there appears to be a slight curvature near the O VI lines. Then the global continuum can be fit with a polynomial of order 2 or 3. Some sightlines with high S/N were classified as "Curved", although with lower data quality we probably would have classified them as "Flat". For the 32 objects in which the continuum fluctuates considerably in the wavelength range 1020–1050 Å the classification "Wavy" is used and a polynomial of order 4 or 5 was needed to fit the global continuum. The difference between "Curved" and "Wavy" is sometimes subjective.

Troublesome continua are provided by the 18 objects for which we classify the continuum as "Wobbly" and which need a polynomial with order >5. These split into the 11 sightlines where we still think that the continuum is trustworthy enough to measure O VI (IRAS F11431−1810, MRC 2251−178, Mrk 36, Mrk 79, Mrk 335, Mrk 1502, Mrk 1513, NGC 595, NGC 3504, NGC 4151 and NGC 7714) and the 7 sightlines for which we decided that the continuum was too uncertain, and which were therefore discarded (NGC 3690, NGC 3783, NGC 4214, NGC 5236, NGC 5461, NGC 7496 and NGC 7673).

3.7. Measurement of S/N Ratio

3.7.1. Flux and rms Measurement

We measured the flux in the O VI λ1031.926 line as the value of the fitted continuum at a wavelength of 1031.926 Å. This is listed in Col. 4 of Table 2. Next, we measured the rms fluctuations around the fitted continuum in the line-free regions used to define the continuum. The resulting values depend on the binning that is used. We measured the rms at 10 pixel binning, i.e. pixels that are about 20 km s^{-1} wide, corresponding to one resolution element. These rms values are listed in Col. 5 of Table 2. Column 6 gives the ratio of the continuum flux at 1031.926 Å to the rms, i.e. the signal-to-noise ratio in the continuum per resolution element (S/N$_{\rm res}$).

For data with S/N>10 we combine 5 detector pixels. This yields bins with a velocity width of about 10 km s^{-1}, or about half a resolution element. For O VI measurements at low S/N ratios we needed to use larger bins. This is possible because the FWHM of the O VI $\lambda\lambda$1031.926, 1037.617 lines is larger than 50 $\mathrm{km\,s^{-1}}$. The choice for the final binning depends on the measured S/N ratio per resolution element. We decided to rebin to 10 pixels if the S/N ratio at 10-pixel rebinning was between 6 and 10, while we rebinned to 15 pixels if this number was between 3 and 6, and to 20 pixels for even lower S/N ratios. We then remeasured the rms. In Col. 7 of Table 2 we list the S/N ratio in the continuum at the final rebinning (S/N_{bin}). This value is always >4 for the objects for which we decided that a measurement was possible.

For faint objects (flux $<4.5\times10^{-15}$ $\mathrm{erg\,cm^{-2}\,s^{-1}}$ $\mathrm{\AA^{-1}}$), the flux that is listed may be affected by inaccuracies in the background subtraction, and thus the value we list is unreliable. That this is the case is shown by a few faint objects for which the measured flux differs between an early short observation and a later long observation. However, without a detailed analysis of every exposure it is not possible to improve the calibration and determine a more precise background correction for each individual object.

3.7.2. Binning

Col. 8 of Table 2 shows that there are 47 objects for which we could use the smallest bins (5 pixels or 10 $\mathrm{km\,s^{-1}}$). These objects all have a S/N_{res} ratio in the continuum >10. For the 30 objects with S/N_{res} ratios between 6 and 10 we decided that rebinning over 10 pixels was appropriate. At lower S/N ratios (for the 42 objects that still have $S/N_{res}>3$) even that was insufficient and we rebinned over 15 pixels, increasing S/N_{bin} to lie between 4.0 and 7.3. For the 97 faintest objects even rebinning to 20 pixels did not increase S/N_{bin} above 4, which is required to measure the O VI absorption.

We note that for spectra that need heavy rebinning, their appearance on the plots of Fig. 1 depends strongly on the pixel at which the binning is started. That is, one can combine pixels 1–15, 2–16, 3–17, 4–18 or 5–19, etc. We used this multiplicity to get a feel for which features are real versus which features are just noise. For the displayed spectra in Fig. 1 we chose a starting pixel such that the absorption profile looks smooth, while the noise fluctuations look realistic. For the targets with high signal-to-noise ratios it hardly matters which starting pixel is chosen, as the pixel-to-pixel fluctuations are small. At the lowest signal-to-noise ratios the pixel-to-pixel fluctuations are large, and the bins wide, and the rebinned spectra always look noisy. It is at intermediate signal-to-noise ratios that the precise choice of starting pixel makes the most difference in the appearance of the spectrum. The measurements of equivalent width and column density are not substantially affected, however as they differ by $<<1\sigma$.

3.7.3. Quality Factor

We also assigned each spectrum an "O VI-quality factor", Q, which is listed in Col. 9 of Table 2. This does not exactly correlate with the chosen final binning. A value Q=4 was given to spectra in which the O VI λ1031.926 line can be clearly measured. This pertains to most spectra with $S/N_{res}>14$. Quality 3 is for good data where a confident measurement can be obtained (S/N_{res}=9–

14). Quality 2 (S/N_{res}=5–9) is for spectra where we think that the measurement is acceptable, but where some problems start to appear – such as uncertainty about the range of integration or even about whether certain features are or are not O VI. Quality 1 (S/N_{res}=3–5) is for spectra for which the measurement is unreliable, but for which we still list the results; these should be treated carefully. Finally, quality 0 pertains both to spectra with very low S/N (S/N_{res}<3) and spectra in which the continuum near O VI λ1031.926 was too uncertain or where intergalactic absorption overlapped the Galactic O VI lines (see Sect. 3.10). In the end, out of the 217 objects in the sample, there are 26 objects of quality 4, 23 of quality 3, 30 of quality 2, 23 of quality 1 and 115 of quality 0.

The quality factor was used to determine when to combine the LiF1A and LiF2B segments (see also Sect. 3.5). For objects with Q=4 and Q=0 only LiF1A was used, while for objects with Q=1, 2 or 3 the two segments were added together. For seven objects this criterion led to a contradiction (ESO 141−G55, H 1821+643, HE 0226−4110, NGC 7469, PG 0844+349, PKS 0405−12 and VII Zw 118). Using just the LiF1A segment would give S/N_{res}<14 and Q=3, while with LiF1A+LiF2B they have S/N_{res}>14 and Q=4; we decided to adopt the higher S/N ratio for these sightlines.

3.8. Removing Contamination by H_2

3.8.1. Contaminating Lines

A complication in measuring the Galactic O VI lines is the presence of other absorption lines in the same spectral region. Near O VI λ1037.617 the H_2 5–0 R(1) λ1037.146, 5–0 P(1) λ1038.156 and 5–0 R(2) λ1038.690 lines are often strong, and lie at −135, 155 and 310 km s^{-1} on the O VI λ1037.617 velocity scale. Further, C II* λ1037.018 is usually present at −173 km s^{-1}. In many cases these lines make the O VI λ1037.617 line only visible over the velocity range between $\sim$−90 and 110 km s^{-1}. Whenever possible, we used the O VI λ1037.617 line to check the results for the O VI λ1031.926 line, but we did not attempt to decontaminate it.

Four lines may contaminate O VI λ1031.926. Cl I λ1031.507 is at −122 km s^{-1} relative to O VI. Cl I is only found when $N(H_2)$ is very high, as it forms when Cl II interacts with H_2 (Jura 1974). Then the HD 6–0 R(0) line at 1031.912 Å (−4 km s^{-1} relative to O VI) is also expected to occur. In fact, toward a number of stars with high $N(H_2)$, one finds that when HD is weakly present, Cl I is still absent. In our sample there is only one sightline showing HD so the Cl I line should not be a problem.

NGC 7469 shows surprisingly strong H_2 absorption ($N(H_2)>10^{19}$ cm^{-2}). Features with equivalent widths of 21±8, 12±6, 29±11, 19±7, 15±7 and 15±7 mÅ can be noticed at the wavelengths of the HD 3–0 R(0) through 8–0 R(0) lines at 1066.271, 1054.433, 1042.847, 1031.912, 1021.456 and 1011.457 Å (Dabrowski & Herzberg 1976). Since all these lines have similar oscillator strengths, we concluded that the narrow feature in the O VI λ1031.926 profile at 1031.91 Å is due to HD 6–0 R(0). This line was removed from the calculation for O VI.

Two H_2 absorption lines often contaminate the O VI λ1031.926 line – the 6–0 P(3) line at

1031.191 Å and the 6–0 R(4) line at 1032.356 Å. On the O VI velocity scale these lie at velocities of -214 and 125 km s^{-1}. Although the column density of local interstellar H_2 is expected to be small along sightlines at high latitude, blending with H_2 has to be considered when interpreting the O VI λ1031.926 absorption line profiles at absolute velocities >100 km s^{-1}.

For sightlines where we find that these H_2 lines contaminate the O VI λ1031.926 line, we removed the H_2 absorption by parametrizing the lines. It is not necessary to model the entire H_2 absorption spectrum for these two rotational states since there are a number of other J=3 and J=4 lines with similar oscillator strengths. These lines therefore have absorption profiles and equivalent widths similar to the 6–0 P(3) and 6–0 R(4) lines and thus can be used to model them without constructing curves of growth. In particular, we used 7–0 P(3) λ1019.506, 5–0 P(3) λ1043.498, 3–0 R(3) λ1067.478, 8–0 P(4) λ1012.261, 5–0 R(4) λ1044.546, and 4–0 R(4) λ1057.379. To these lines we fitted gaussian profiles, deriving FWHMs and absorption depths. We averaged these parameters (weighted by S/N) for the three J=3 and the three J=4 lines, respectively, and reconstructed the H_2 absorption as a gaussian in the vicinity of the O VI λ1031.926 absorption with these averaged parameters. We cross-checked the validity of our model by comparing the shape and strength of the H_2 absorption with other J=3 and J=4 lines that have higher and lower oscillator strengths. The H_2 absorption then was removed from the O VI profile by converting the H_2 absorption depth into a peak optical depth (τ_0=$-$ln[1$-$depth]), and assuming a gaussian optical depth profile ($\tau(v) = \tau_0 \exp[-(v - v_0)^2/b^2]$). The original continuum, c, was thus replaced by $c \exp -\tau(v)$.

Columns 15 and 16 of Table 2 list the basic H_2 information for each of the sightlines. In Col. 15, we show the maximum value of the rotational state J for which absorption is found, where a dash indicates those sightlines where no H_2 was found. Column 16 contains a "y" for those sightlines where H_2 contaminates the O VI absorption and an "n" otherwise.

3.8.2. Discussion of Contaminated Sightlines

There are 77 sightlines in which the O VI λ1031.926 line is not contaminated by H_2 absorption. In 19 of these there is no discernable H_2. For the cases with high S/N ratio (Q=4; Mrk 279, Mrk 817, NGC 1705, PKS 2155$-$304 and vZ 1128) the 3σ detection limit on $N(H_2)$ in each rotational level is about 10^{14} cm^{-2}. For lower quality sightlines (Q=2, 3), the limit is more like 4×10^{14} cm^{-2}. At even lower S/N the quality of the spectrum may just not be sufficient to discern the H_2 that may still be present. The sightlines with little or no H_2 concentrate in the regions l=0–120°, b>40°, l=210–60°, b<$-$40°. In 58 sightlines low-velocity H_2 absorption is detected that does not contaminate the O VI λ1031.926 absorption. In 15 of these the highest rotational level we can discern is J=1, in 6 it is J=2, and in 24 it is J=3. Finally, in 13 sightlines J=4 is present, but neither J=3 or J=4 contaminate the O VI. For the latter 37 sightlines, instead of fitting other J=3 or J=4 lines to find the parameters of the H_2 lines near O VI λ1031.926, we measured the parameters of the 6–0 P(3) and 6–0 R(4) lines by directly fitting a gaussian to the absorption profile.

In 5 sightlines (Mrk 357, Mrk 876, PG 0832+675, PG 1116+215 and PG 1351+640) the J=3 and J=4 lines show two components. One is at a velocity near 0 $\mathrm{km\,s^{-1}}$, and is associated with the low-velocity H I component. The other lies near −50 $\mathrm{km\,s^{-1}}$ and is associated with intermediate-velocity H I (having v_{LSR}=−90 to −40 $\mathrm{km\,s^{-1}}$). In fact, in about 50% of the sightlines toward which intermediate-velocity H I is seen, intermediate-velocity H_2 absorption is detected. This is described in a separate paper (Richter et al. 2002).

We now discuss the 25 contaminated sightlines. First we note that for the sightline to NGC 3783 the contamination by H_2 is so severe that we cannot use this sightline for measuring Galactic O VI (see Sembach et al. 2001a).

Five different kinds of H_2 contamination occur.

(a) Toward Mrk 116, NGC 3310 PG 1004+130 and PHL 1811 the positive-velocity edge of the Galactic absorption abuts the 6–0 R(4) line at 125 $\mathrm{km\,s^{-1}}$. In these cases the contamination is minor and mostly limits our ability to precisely determine the extent of the O VI absorption.

(b) Toward 3C 273.0, ESO 141−G55, Mrk 509, Mrk 734, and PG 0844+349 the 6–0 R(4) line is present in the middle of a wide high-positive velocity O VI wing that merges with the Milky Way thick disk absorption. This H_2 line is always sufficiently weak that we are confident that the O VI measurements are still reliable.

(c) Toward Mrk 290, Mrk 506, Mrk 876, Mrk 1502 and PHL 1811 there is a HVC component between velocities of $\sim$−200 and −100 $\mathrm{km\,s^{-1}}$, and the negative-velocity edge of that component merges with the H_2 J=3 absorption at $\sim$−214 $\mathrm{km\,s^{-1}}$, making the velocity range of the HVC component somewhat uncertain. The column density measurement is only weakly affected, however.

(d) Toward Mrk 304, Mrk 1513, NGC 7714, as well as UGC 12163 the positive-velocity edge of a HVC component at v_{LSR}<−250 $\mathrm{km\,s^{-1}}$ gets somewhat confused with H_2. However, this has only a minor influence on the measurement of O VI.

(e) Toward Mrk 335, Mrk 352, Mrk 357, Mrk 509, NGC 595, NGC 7469, PG 0052+251, and PG 2349−014 a strong J=3 line at $\sim$−214 $\mathrm{km\,s^{-1}}$ sits between two HVC components with central velocities of $\sim$−300 and $\sim$−180 $\mathrm{km\,s^{-1}}$. In these sightlines the fit to the other J=3 lines is reliable enough to conclude that the absorption that is apparently centered near the −214 $\mathrm{km\,s^{-1}}$ is a mix of the 6–0 P(3) line and O VI absorption. After dividing out the H_2 line, the O VI absorption profile looks simple, as can be seen from the apparent column density plots shown in Fig. 1 for these sightlines.

In this category (e), an especially difficult case of contamination is presented by H 1821+643 (see its spectrum in Fig. 1). Absorption at velocities of $\sim$−100 to −160 $\mathrm{km\,s^{-1}}$ is interpreted as associated with the Outer Arm, a distant Galactic spiral arm (e.g., Kepner 1970, Haud 1992). For the H_2 J=3 line we derive a wide (FWHM 35 $\mathrm{km\,s^{-1}}$) and deep (32% absorption) profile, which separates two O VI features. The O VI absorption extends up to −285 $\mathrm{km\,s^{-1}}$ on the negative-velocity side, and to about −160 $\mathrm{km\,s^{-1}}$ on the positive-velocity side, where the O VI absorption suddenly gets deeper. However, because of the uncertainties in deriving the H_2 parameters, the systematic errors in these components are large.

The spectrum of H 1821+643 is further contaminated by a strong (saturated) O VI line near 0 $\mathrm{km\,s^{-1}}$, which is associated with the environs of the planetary nebula K1-16, which lies about

96″ away (Savage et al. 1995). This absorption was fitted and removed from the calculation of the Galactic N(O VI).

3.9. Extragalactic Absorption Lines

A source of contamination other than that by Galactic H_2 is provided by redshifted lines from the neutral and low-ionization ISM in some of the background targets or from intervening objects. We refer to the former as "intrinsic absorption" and to the latter as "intergalactic absorption". We searched the velocity range −1200 to 1200 km s^{-1}. The lower limit is set by the presence of geocoronal O I* emission lines near 1028 Å, which make absorption hard to detect at more negative velocities. The upper limit is set by the low-velocity interstellar C II λ1036.337 line. In this velocity range we find 169 absorption features in 101 of the 119 sightlines with sufficient S/N ratio (excluding O VI and H_2 lines). Of these, 37 can be identified with intrinsic Lyβ absorption, 13 with intrinsic O VI lines, 29 with other intrinsic absorption lines, and 18 with interstellar C II. In addition, toward NGC 7673 we find two high-velocity O VI features, which are clearly present, but whose measurement is too uncertain because of the intrinsic wide Si II λ1020.699 line. This leaves 61 features which are confirmed, probably or possibly intergalactic.

For ten features we did not manage to find a reasonable identification, for several reasons. (a) Some are weak, are only seen in one channel and/or may not be real, while at the same time they are not at the velocity expected for intergalactic Lyβ based on the presence of galaxy groups in the sightlines or we find no Lyα at the same velocity (toward HE 0238−1904, Mrk 304, Mrk 506, Mrk 926 (2 features), Mrk 1095, PG 0947+396 and PG 1211+143). (b) The absorption at 290 km s^{-1} toward HE 1228+0131 is a confusing blend, of which only some parts can be identified. (c) The feature at 425 km s^{-1} toward PG 1211+143 cannot be Lyβ, and while it may be O VI, this is impossible to confirm. No other intergalactic lines fall near the velocity of the feature. These ten unidentified features are indicated by a "?" in Fig. 1.

We discuss the intrinsic lines in the next subsection, the intergalactic Lyβ in the one after that, and then we summarize the remaining intergalactic features.

3.10. Removing Contamination by the AGN

Here we discuss the expected and detected intrinsic absorptions in the velocity range between −500 and 500 km s^{-1} relative to O VI. To check whether such absorption can occur, we calculated the redshifted position for Si II λ1020.699, O I λ988.773, C III λ977.020, S III λ1012.501, Lyβ λ1025.722, Lyγ λ972.537, Lyδ λ949.743 and Lyϵ λ937.804, and we noted the objects for which any of these lines would lie within ±500 km s^{-1} from the Galactic O VI absorption. This is the case for the sightlines discussed below. For all other sightlines confusion with intrinsic absorption does not occur. All velocities listed below refer to those on the Galactic O VI λ1031.926 velocity scale.

Intrinsic Si II absorption is expected near O VI λ1031.926 in 6 sightlines. It is indeed seen near the expected velocity (but not contaminating O VI) toward NGC 3690, NGC 3783, NGC 7714 and Tol 1924−416. For NGC 3991 the intrinsic Si II λ1020.699 line lies at $v_{\rm LSR}$=−110 km s^{-1}, but is relatively weak and shows a simple profile; we thus fit and remove it from the Galactic O VI line. Toward NGC 7673, however, the intrinsic Si II λ1020.699 line is broad and strong. We also detect very broad and strong intrinsic O I λ988.773 and Si II λ989.873 lines. Using that the ratio of optical depths of the two Si II lines is 10.1, the expected optical depth for the intrinsic Si II λ1020.699 line is on the order of 0.1–0.5. Therefore, the continuum near O VI λ1031.926 is too uncertain, leading us to discard NGC 7673 from the Galactic O VI sample.

The intrinsic O I λ988.773 line is expected to lie near Galactic O VI in three AGNs. A broad line, centered at 290 km s^{-1} is seen toward Mrk 54; this causes sufficiently bad contamination of the Galactic O VI that we discarded Mrk 54 from the final sample. The possible O I λ988.773 line is not detected at -175 km s^{-1} toward Mrk 506 or at -145 km s^{-1} toward NGC 985.

Intrinsic C III λ977.020 is seen at 500 km s^{-1} toward 3C 382.0, where it does not contaminate Galactic O VI. Toward ESO 265$-$G23 intrinsic C III is expected at -55 km s^{-1}, but not seen. However, toward IRAS 09149$-$6206 the intrinsic C III line is centered at 320 km s^{-1}, very broad and confuses the positive-velocity wing of Galactic O VI in such a manner that we decided to discard this object from our sample.

Toward ESO 350$-$IG38 a wide intrinsic S III λ1012.51 overlaps most of the Galactic O VI absorption. Corresponding features are also seen in many other low, medium and high-ionization lines. We therefore did not include ESO 350$-$IG38 in the final sample.

Intrinsic Lyβ occurs at -165 km s^{-1} in the spectrum of NGC 7496. This line is so strong that it completely covers Galactic O VI and makes the spectrum unusable for the current project. Toward NGC 3504 the intrinsic Lyβ line was expected at -277 km s^{-1}, but there only seems to be weak Lyβ absorption centered near -440 km s^{-1}. In many other cases we see strong intrinsic Lyβ with broad damping wings, centered several Å from 1032 Å. Except for NGC 1395, NGC 1404 and NGC 1407 the flux near 1032 Å remains sufficiently high to measure O VI λ1031.926.

Intrinsic Lyγ might occur at 20 km s^{-1} toward Mrk 1502, and at 260 km s^{-1} toward Ton S180, but no absorption is seen, nor are there corresponding Lyβ lines.

Intrinsic Lyδ is not present at -15 km s^{-1} toward Mrk 1383, as is confirmed by the absence of Lyγ and Lyβ. Toward PG 1351+640, however, two intrinsic Lyδ lines are clearly present at velocities of -560 and -340 km s^{-1}, covering the O VI velocity range between -700 and -260 km s^{-1}. This almost abuts the high-negative velocity O VI absorption associated with HVC complex C, but there does not appear to be contamination. A similar Lyδ line stays to the short wavelength side of the Galactic O VI line toward PG 1411+442 (centered at -575 km s^{-1}, extending to -150 km s^{-1}).

Intrinsic Lyϵ is seen at -410 km s^{-1} toward PG 1404+226.

A special case is presented by Tol 0440$-$381, where no known intrinsic line overlaps Galactic O VI, but where there is nevertheless an apparent emission feature located between -400 and 0 km s^{-1} on the O VI velocity scale. This unidentified feature strongly contaminates Galactic O VI, and we therefore do not include Tol 0440$-$381 in the final sample.

3.11. Removing Contamination by Nearby Galaxy Groups

3.11.1. Identifying Nearby Galaxy Groups

To identify the intergalactic Lyβ lines associated with nearby galaxy groups we used two checks. First, we searched for matching Lyα absorption for those objects for which a longer wavelength UV spectrum was also available, taken with one of the spectrographs on the *Hubble Space Telescope* – either the *GHRS (Goddard High Resolution Spectrograph*, the *FOS (Faint Object Spectrograph)* or the *STIS (Space Telescope Imaging Spectrograph)*. Second, we checked whether the line of sight passes through a galaxy group, in which case the likelihood of detecting Lyβ associated with that group is increased.

To find galaxy groups, we overlaid the position of each object on a map of galaxies from Tully's (1988) "Nearby Galaxy Catalog". This lists 2367 galaxies with systemic velocities less than 3000 $\mathrm{km\,s^{-1}}$. Each of these was assigned to one of 36 galaxy "galaxy groupings". Tully's terminology for these was "clouds", but that could lead to confusion with interstellar features. These "galaxy groupings" are much bigger than the more concentrated galaxy groups and clusters usually discussed – they may encompass several groups. A list of intersected "galaxy groupings" is given in the notes to Table 2. In the overlays we also included a circle showing the position and size of the 176 groups catalogued by Geller & Huchra (1983, 1984). These authors listed the central position, velocity and diameter of galaxy groups, defined as regions with a galaxy density enhancement greater than 20, in a magnitude-limited sample of galaxies brighter than m=13.2; this sample goes out to a velocity of $\sim$8000 $\mathrm{km\,s^{-1}}$.

Columns 12, 13 and 14 of Table 2 summarize the results. Column 12 gives a code classifying the Lyβ absorption line near O VI λ1031.926, as described below; a detailed discussion of each individual case is given in the Appendix. If the sightline intersects a galaxy group, Col. 13 of Table 2 lists the group number as given by Geller & Huchra (1983, 1984), and Col. 14 the "galaxy grouping" number given by Tully (1988).

3.11.2. Detected Intergalactic Lyβ

The codes used in Column 12 of Table 2 indicate the kind of detection that was made. "NoGrp" implies that the sightline does not pass through a nearby galaxy group (38 objects). "GrpNoIGM" is for sightlines that do pass through a group, but where no extra features are seen in the spectrum (57 objects), while "Grp" is used for the 46 sightlines passing through a group but for which the spectrum has insufficiently high S/N ratio. We note that since the detection limit strongly varies with the quality of the spectrum, it is quite likely that Lyβ absorption associated with nearby galaxy groups could be present in many of the objects given code "GrpNoIGM".

The entry "IntrLyβ??' is used for six objects that are part of a group in the Tully catalogue, and where intrinsic Lyβ might be expected, but where the S/N ratio is too low to see this. "IntrLyβ" is given for the 39 objects where an intrinsic Lyβ line with damping wings is present.

There are 40 intergalactic Lyβ absorptions detected toward 30 objects, at varying levels of confidence. Three entries are coded "NoGrpLyβ??" (3C 382.0 – 2 possible Lyβ, HE 0226−4110 and

PG 2349−014). Here a fairly strong feature is present, and it is possible that it is Lyβ, although the sightline does not intersect a galaxy group, nor is a spectrum for Lyα available. Entries "GrpLyβ??" are given for PG 1302−102 and PG 1352+183). In these low S/N sightlines there is a feature at a velocity similar to that of the galaxy group that is intersected, but the spectrum is too noisy to conclude with confidence that the feature is Lyβ (or sometimes even whether it is real). Toward Mrk 478 and PG 1444+407 such a feature occurs in addition to a positive identification. "GrpLyβ?' is given for four objects (Mrk 106, Mrk 304 – 2 features, PG 0832+251 and PG 0947+396). These sightlines are projected onto a nearby group, and a feature that is probably Lyβ is seen in the correct velocity range, but there is no spectrum that would allow confirmation using Lyα.

A code of "GrpLyβ" is used for the 13 objects where intergalactic Lyβ absorption from a known intervening group is confirmed by a matching Lyα line (3C 273.0 – 2 Lyβ; HS 1543+5921; Mrk 205; Mrk 335 – 2 Lyβ; Mrk 478; Mrk 734 – 2 Lyβ; Mrk 817; Mrk 876; NGC 7469; PG 1004+130; PG 1211+143; PG 1259+593 – 2 Lyβ; and PG 1444+407). For several of these objects, the Lyα absorption line was previously shown by Penton et al. (2000). Finally, confirmed Lyβ not associated with a group is found toward Mrk 509, NGC 4670 and VII Zw 118 (code "Lyβ").

Toward five objects the confirmed intergalactic Lyβ is at a velocity such that it contaminates the O VI λ1031.926 line (3C 232, HE 1228+0131 – 3 Lyβ, Mrk 771, PG 1048+342 and PG 1216+069) – code "ContamLyβ". Only in the case of Mrk 771 was it possible to use the O VI λ1037.617 line to measure N(O VI).

In addition to the unidentified features, the identified intrinsic absorption lines, and the identified or probable Lyβ absorptions, 21 other features are found in 18 sightlines. Three of these are high-redshift Lyγ (toward HS 0624+6907, PG 1211+143 and PG 1415+451) or C III λ977.020 (toward Mrk 1513 and PG 1211+143). Another three are high-redshift C II $\lambda\lambda$903.624, 903.962 (toward PG 1116+215 and PG 1302−102). These identifications are based on the presence of many other Lyman lines at the same redshifts. The remaining 13 features are confirmed or probable low-redshift (v<1200 km s^{-1}) O VI absorbers. These will be described in a separate paper.

4. MEASURING THE O VI

4.1. Velocity Range

4.1.1. Determining Velocity Limits

Of the 219 objects in the sample, 121 were deemed to have a signal-to-noise ratio sufficiently high to be of interest (S/N>3 per resolution element after combining the LiF1A and LiF2B segments). Of these 121 objects, Mrk 153 and PG 1011−040 were eliminated because the data were obtained as part of guest observer programs with science goals similar to those of our program. Six were eliminated because the continuum placement was too uncertain (NGC 604, NGC 3690, NGC 4214, NGC 5236, NGC 5253, NGC 5461). Finally, eleven more were eliminated because Galactic, intrinsic or intergalactic absorption either was too confusing or overlapped the O VI λ1031.926 line (ESO 350−IG38, IRAS 09149−6206, HE 1228+0131, Mrk 54, NGC 592, NGC 3783, NGC 7496, NGC 7673, PG 1048+342, PG 1216+069, Tol 0440−381). This left a sample of 100 extragalactic and 2 stellar objects for which we could measure the Galactic O VI lines.

Toward most objects in our final sample, we find a strong O VI λ1031.926 line centered near a velocity of 0 $\mathrm{km\,s^{-1}}$. This component clearly is associated with the Milky Way. In about two-thirds of the sightlines a second component is also found, at velocities $|v_{\mathrm{LSR}}|$>120 $\mathrm{km\,s^{-1}}$. Differential Galactic rotation can produce velocities up to about ±150 $\mathrm{km\,s^{-1}}$ in the Galactic plane, depending on the Galactic longitude; lower maximum velocities are expected at high latitudes. Therefore, any O VI absorption at high velocities cannot be part of the rotating Galactic disk. Fortunately, the high-velocity component and the Milky Way absorption can usually be fairly cleanly separated from each other.

4.1.2. Distribution of Velocity Limits

The top panel of Fig. 5 shows the distribution of the minimum and maximum velocity to which the Milky Way absorption extends. The thin solid line gives the histogram for all sightlines, the thick line excludes the eleven sightlines for which only an upper limit could be derived, as well as the 26 sightlines where it was difficult to separate the Milky Way and high-velocity absorption. These distributions show that both at the negative and the positive velocity edge the Galactic O VI absorption typically extends to anywhere between ±50 and ±120 $\mathrm{km\,s^{-1}}$, with ±90 $\mathrm{km\,s^{-1}}$ as the average. The spike at 100 $\mathrm{km\,s^{-1}}$ is artificial and has to do with some of the sightlines where the separation between the Milky Way and high-velocity absorption was difficult (see below).

The bottom two panels of Fig. 5 show the velocity limits for the high-velocity O VI components. Again, the thin solid line includes all sightlines, while the thick solid line excludes the difficult ones. This distribution shows that O VI absorption with $|v_{\mathrm{LSR}}|$=100 to 400 $\mathrm{km\,s^{-1}}$ is common, and has no preferred velocity limits. We find only eight sightlines with O VI at velocities between 400 and 1200 $\mathrm{km\,s^{-1}}$, and in all cases this can be identified as intergalactic.

For the majority of sightlines (80 out of 102) the Galactic O VI λ1031.926 line extends no further than ±120 $\mathrm{km\,s^{-1}}$ and in 58 of these it is easily separated from high-velocity absorption. In only five sightlines does it extend slightly further (to ±130–140 $\mathrm{km\,s^{-1}}$ (HE 0226−4110, Mrk 209, NGC 3310, PG 1004+130 and PKS 0558−304). For the eleven sightlines where we can only set an upper limit, a velocity range that seemed reasonable was chosen to determine the detection limit (HE 0450−2958, HE 1115−1735, HE 1326−0516, Mrk 205, Mrk 926, NGC 588, NGC 595, NGC 3504, PG 0052+251, PG 2349−014 and SBS 0335−052). Three sightlines lie projected on the Outer Arm, a distant Galactic spiral arm (Habing 1966, Kepner 1970, Haud 1992). In the direction of H 1821+643, differential Galactic rotation may produce velocities for gas in the outer galaxy as high as the −145 $\mathrm{km\,s^{-1}}$ seen in the O VI line. Similarly, toward 3C 382.0 velocities as high as −130 $\mathrm{km\,s^{-1}}$ can easily be understood. Thus, for these two cases, the absorption over the full observed velocity range was considered to be Galactic. In the third sightline crossing the Outer Arm (HS 0624+6907) the O VI absorption does not extend as far as the H I.

4.1.3. Sightlines with a Difficult Separation

For 26 objects the separation between the Galactic and high-velocity component was not clear-cut. These fall into five categories.

(a) Nine sightlines lie projected onto the HVC complex C, which is a large, infalling cloud with a metallicity of ∼0.1 solar, lying more than 4 kpc above the Galactic plane (e.g., Wakker 2001). In H I 21-cm emission, complex C is seen at velocities between −180 and −100 km s^{-1}. In each of these directions, the O VI profile extends out to rather high negative velocities (−150 to −260 km s^{-1}). Clearly, there is O VI absorption associated with HVC complex C. In 5 of the 9 sightlines, there appear to be two components in the O VI profile (Mrk 279, Mrk 290, Mrk 817, PG 1259+593 and PG 1626+554), one of which more or less covers the velocity range of the H I. We then placed a cut between the Galactic and HVC absorption at about the velocity that separates the O VI components. In the remaining 4 directions (Mrk 501, Mrk 506, Mrk 876 and PG 1351+640) this cannot be done. Instead, we decided to cut at a velocity of −100 km s^{-1}, which seems a reasonable compromise, especially since this velocity is among the most common ones for directions where the extent of the Galactic O VI absorption is clear (see Fig. 5).

(b) Two sightlines intersect HVC complex A, known to have a z-height of 5.7±1 kpc (Wakker 2001). In one of these sightlines (Mrk 116), the O VI extends to about −125 km s^{-1}, whereas the H I emission lies between −205 and −125 km s^{-1}. So, no separate HVC component was included. In the other sightline (Mrk 106), the O VI goes to −150 km s^{-1}, while the H I lies between −190 and −120 km s^{-1}, as well as between −70 and 30 km s^{-1}. In this case, the O VI absorption between −150 and −100 km s^{-1} is presumed to have some association with complex A.

(c) A group of eleven sightlines in the quadrant l>180°, b>0° show extended positive-velocity wings in O VI, with velocities up to 275 km s^{-1}. An O VI component can be discerned in six of these (ESO 572−G34, HS 1102+3441, Mrk 734, Mrk 1383, PG 0947+396 and PG 1116+215), separated from the Galactic absorption at velocities of 100, 95, 140, 100, 100 and 115 km s^{-1}, respectively. For the other five sightlines (IRAS F11431−1810, Mrk 421, PG 0953+414, PG 1001+291 and Tol 1247−232), there is no such separation, and instead we decided that the best we could do is to cut between the Galactic and high-velocity absorption at a velocity of 100 km s^{-1}.

(d) In part of the southern sky (l<180°, b<0°) many sightlines exhibit O VI absorption at high negative velocities. For two of these (Mrk 335, and PKS 2155−304) the separation between Galactic and high-velocity absorption is not clear-cut. We decided to separate the two at velocities of −75 and −85 km s^{-1}, respectively, since a) at these velocities the absorption appears minimal and b) similarly low negative limits occur toward other sightlines in this part of the sky: MRC 2251−178 (−65), Mrk 304 (−40), Mrk 1095 (−35), Mrk 1502 (−35), Mrk 1513 (−75), NGC 7469 (−65), NGC 7714 (−60), PHL 1811 (−65).

(e) Finally, in the directions of Fairall 9 and PKS 2005−489, there is no separation between the Galactic and high-velocity component. The latter extends out to velocities of 275 and 225 km s^{-1}, respectively, which is clearly incompatible with differential Galactic rotation. For PKS 2005−489, we decided to place a cut at 120 km s^{-1}, where at least there is an inflection in the profile. For Fairall 9, we arbitrarily selected 100 km s^{-1} as the place to cut.

For each object, Cols. 17 and 18 of Table 2 list the final velocity ranges within which we decided that O VI absorption is associated with the Milky Way. An "x" precedes or follows values where the separation between the Galactic and high-velocity component is not clear, but where it appears to be possible to discern separate components. A pair of "[" and "]" precedes or follows values where the separation between the Galactic and high-velocity absorption was based on a rule rather than on features in the spectrum, as described in detail above.

In Cols. 21 and 22 of Table 2 we list the velocity ranges used to measure the parameters of the high-velocity O VI absorption. Column 20 gives the classifications for the high-velocity gas, which will be discussed in detail by Sembach et al. (2002b).

4.2. Equivalent Width Measurement

4.2.1. The Equivalent Width and its Errors

Having identified the velocity range of the absorption associated with the Galaxy and with high-velocity gas, we next calculated equivalent widths by a straight integration of the line profile:

$$\mathrm{W} = \int_{\lambda_{\mathrm{min}}}^{\lambda_{\mathrm{max}}} \left(1 - \frac{F_\lambda}{C_\lambda}\right) d\lambda,$$

where F_λ is the observed flux, C_λ is the continuum flux and $\lambda_{\mathrm{min/max}}$ are the wavelengths corresponding to the velocity range of the absorption. The resulting equivalent widths are listed in Cols. 19 and 23 of Table 2.

We calculate five contributions to the error in the equivalent width: random noise, the continuum fit, fixed-pattern noise, uncertainties in the integration range and uncertainties in removing H_2 contamination. The random-noise and continuum-fit error are combined in quadrature into a "statistical error", while the fixed-pattern error, the velocity-limits error and the decontamination error are combined in quadrature into a "systematic error". These are both included in Col. 19 of Table 2 for the Milky Way component and in Col. 23 for the high-velocity absorption. The statistical error indicates how accurately the measurement can be made, while the systematic error indicates how much the listed equivalent width could be offset from the actual value.

The *FUSE* calibration pipeline provides an error associated with random noise in the flux for each pixel. This is mainly the poisson error (square root of counts), but a small background error is also included. This yields an error in the equivalent width of:

$$\sigma_{\mathrm{W,noise}} = \sqrt{\left(\Sigma \left[\frac{\delta F_\lambda}{C_\lambda}\, d\lambda\right]^2\right)}.$$

The second error contribution comes from the uncertainty in the placement of the continuum. The method of fitting Legendre polynomials (Sembach & Savage 1992) produces an error in the coefficients and this can be converted to an error in the placement of the continuum for each pixel. Since these errors are correlated, the associated error in the equivalent width becomes:

$$\sigma_{\mathrm{W,cfit}} = \Sigma \left[\frac{\delta C_\lambda}{C_\lambda}\, \frac{F_\lambda}{C_\lambda}\right].$$

The third error is from the detector "fixed-pattern noise". This takes into account the possibility that there are pixel-to-pixel sensitivity variations in the detector. However, because the placement of the spectrum on the detector can vary, there can be variations in the correspondence between a particular pixel on the detector and a particular wavelength. Thus, a fixed-pattern feature is not always present at the same wavelength. By studying the good-quality spectra and noting that sometimes there appear to be weak, narrow features present (e.g., at -360 km s^{-1} toward 3C 273.0) and measuring these features, we estimate that a reasonable fixed-pattern error is ∼6.8 mÅ, which is the equivalent width of a 10% absorption that is one resolution element wide.

Fourth, there are multiple possible ways in which the velocity limits of the integration can be uncertain, especially for noisy spectra and for sightlines where the separation between the high-velocity and Milky Way absorption is not clear. We estimate this contribution to the systematic error as:

$$\sigma_{\mathrm{W,vlim}} = |\mathrm{W}(v_- - 15) - \mathrm{W}(v_- + 15)| + |\mathrm{W}(v_+ - 15) - \mathrm{W}(v_+ + 15)|,$$

where v_- gives the negative side of the integration and v_+ the positive side.

Finally, for sightlines where the O VI absorption is contaminated by H_2 we systematically varied the parameters of the H_2 lines (by 10 km s^{-1} in width, 20% in depth, 10 km s^{-1} in velocity), and then recalculated the equivalent width. We then find the error associated with decontamination as half of the difference between the most extreme values. For sightlines where the Milky Way component or the positive-velocity HVC are contaminated by the 6–0 R(4) line at 1032.356 Å, this error is at most 5 mÅ. In the three sightlines (Mrk 290, Mrk 506 and Mrk 876) where the O VI absorption associated with complex C abuts the 6–0 P(3) line at 1031.191 Å, the decontamination error is also <5 mÅ. However, the decontamination error is large for the high-negative velocity O VI absorption on all twelve sightlines in the region l=30° to 130°, b=−60° to −25°. Usually it lies in the range between 12 and 25 mÅ, but it can be as high as 36 mÅ (for Mrk 352).

4.2.2. Error Distributions

Figure 6 shows the distributions of the measured equivalent widths, random-noise errors, continuum-fit errors and velocity-limits errors. Different panels are given for spectra of different quality, separately for Galactic and high-velocity O VI. For the thick disk the range in the measured equivalent widths is independent of the spectral quality, giving confidence in the measurements at low S/N ratios. Equivalent widths for the high-velocity component are generally lower, and fainter components are detected in higher quality spectra, suggesting that we are missing a substantial fraction of the high-velocity O VI in the lower S/N spectra. This is discussed in more detail in Sect. 5.2.

In Fig. 7 we plot the different errors against each other. The top panel shows that the error associated with random noise ($\sigma_{\mathrm{W,noise}}$) correlates with that associated with the continuum fit ($\sigma_{\mathrm{W,cfit}}$). The different symbols indicate different orders for the local continuum (see Sect. 3.6). If this order is 1 (plus symbols in Fig. 7) the continuum-fit error is 0.30±0.02 times the random-noise

error (with correlation coefficient 0.86), while if the fit order is 2 (filled circles in Fig. 7) the ratio of the errors is 0.66±0.04 (with correlation coefficient 0.89). For higher order fits (open circles) the ratio is 0.34±0.11 with correlation coefficient 0.66.
Thus, on average, including the error in the continuum placement is equivalent to increasing the random-noise error by a factor $\sqrt{1+0.3^2}$=1.04 (order=1) or a factor $\sqrt{1+0.66^2}$=1.2 (order=2). However, the ratio is not a constant, and there are ten sightlines where the ratio is >0.8. The ratio also depends on the order of the fit. Therefore, the continuum-fit error needs to be calculated separately for each spectrum.

The random-noise and continuum-fit errors correlate with spectral quality (by definition). They range from ∼30–60 mÅ at Q=1 to ∼5–15 mÅ at Q=4. As expected, the systematic error associated with the selection of the velocity integration range is more or less independent of spectral quality. It also has a much wider distribution, varying from low values of ∼10 mÅ to as much as 60 mÅ.

Panel b of Fig. 7 compares the continuum-fit error determined from fitting Legendre polynomials to the error that follows from an alternative method that is often used. In this method the continuum is shifted up and down by one-third of the rms fluctuations in the flux, and the continuum placement error is found as half of the difference of the two resulting equivalent widths. Figure 7b shows that this error, $\sigma_{\rm W,rms/3}$ is on average 1.7 times the Legendre fit error if the polynomial fit has order 1 (with correlation coefficient 0.9), but also that it is on average only 0.8 times as large (with correlation coefficient 0.9) for a fit order of 2. Thus, the ±rms/3 method of estimating continuum errors tends to overestimate these for flat continua, but gives reasonable answers for continua fit with a second-order polynomial.

Finally, in Fig. 7c we show that there is no correlation between the random-noise error and the velocity-limits error. The correlation coefficient is only 0.12. This is to be expected, as the velocity-limits error is a measure of the difficulties with defining the velocity integration limits intrinsic to the spectrum, while the random-noise error is simply a measure of data quality.

4.3. Column Density Measurement

4.3.1. Background Information

To derive column densities, we used the apparent optical depth method (Savage & Sembach 1991), which is applicable if the spectral line to be measured is unsaturated and nearly fully resolved. Using this method, the total column density is measured by first converting each absorption profile to an apparent optical depth profile:

$$N_a(v) = \frac{m_e c}{\pi e^2}\, f\, \lambda\ \ln \frac{C(v)}{F(v)},$$

where $C(v)$ is the continuum as a function of v, $F(v)$ the observed flux, and the oscillator strength f of the O VI λ1031.926 line is 0.133 (Morton 1991). This is then integrated over the chosen velocity range. The error in the column density is derived in a manner similar to that described above for the derivation of the equivalent width error. The resulting column densities are not listed in this paper, but in the companion papers that discuss in detail the Galaxy's thick disk (Savage et al. 2002) and the high-velocity O VI (Sembach et al. 2002b).

In those papers we also list a measure of the position and width of the O VI absorption. These are calculated as:

$$\bar{v}_{\rm obs} = \int \frac{v\, N_a(v)\, dv}{N_a}; \quad b = \left[2 \int \frac{(v - \bar{v}_{\rm obs})^2\, N_a(v)\, dv}{N_a} \right]^{1/2}.$$

The average velocity is the column density weighted mean. The width parameter, b, is numerically similar to the Doppler spread parameter. See Savage et al. (1997) for more discussion of the usefulness of b. The ratio between the FWHM and b is FWHM=$\sqrt{4 \ln 2} b$. The values and distribution of $\bar{v}_{\rm obs}$ and b are discussed in the companion papers.

4.3.2. Comparing the Two O VI Lines

If the $N_a(v)$ profiles of the two lines of the doublet match, one concludes that there is no saturation. If they do not match, there probably is saturation or some other problem with the observation or the placement of the continuum. We checked the O VI λ1037.617 lines for all 60 objects with S/N ratio >6.5. For 20 Milky Way and 2 HVC components it was possible to calculate the ratio of the column density derived from the O VI λ1031.926 line to that derived from the O VI λ1037.617 line, although the velocity range over which the comparison is possible is usually narrower than that used to calculate the total O VI column density. The velocity ranges and the ratio of the O VI λ1031.926 and O VI λ1037.617 column densities are given in the Appendix. For the other sightlines with S/N ratio >6.5 the comparison between the two O VI lines is strongly affected by the uncertainties introduced by a curvature in the continuum or by the encroachment of H_2 lines. In two cases where saturation appears present (Mrk 771 and Mrk 876) the O VI λ1037.617 line is in fact contaminated by weak Lyβ absorption at 3485 km s^{-1}; the corresponding Lyα lines are clearly detected in the *STIS* spectra of these objects.

Figure 8a shows the ratio for the 22 components, with the error calculated by combining the random-noise error and continuum fit errors, but ignoring the systematic errors. For 17 of the 22 components, the ratio is 1 within the 1σ error bar. In the one direction where the ratio is large (1.60±0.18 for Mrk 421) the profile comparison (see Fig. 1) shows that there is some saturation, though the O VI λ1037.617 line is rather noisy. For PG 1259+593, Mrk 817, Mrk 1383 and 3C 273.0 the saturation is less obvious, but the continua are defined well enough that the ratio calculation is trustworthy, and thus we conclude that there is slight saturation toward these sightlines.

In Fig. 8b we plot the ratio against the column density derived from the O VI λ1031.926 line. This shows that the five sightlines with slightly saturated O VI do not seem to concentrate toward high O VI column densities. We therefore conclude that higher values of N(O VI) are not systematically more affected by saturation.

Since in the majority of cases there are no significant differences between the column density derived from the weaker O VI λ1037.617 line with that derived from the stronger O VI λ1031.926 line, we conclude that it is justified to integrate just the O VI λ1031.926 line to derive column densities. For about 20% of sightlines some saturation may occur, which would result in corrections on the column density on the order of a factor 1.2, or 0.08 in the log. This is about twice the typical statistical error for high quality sightlines, but comparable to the typical statistical error for sightlines with Q=2. In the subsample of 20 sightlines where a check is possible, we found only one sightline where stronger saturation appears to be present.

Thus, although there will be a (limited) number of sightlines where saturation occurs, and where the derived column density is slightly in error, the differences are sufficiently small that they should not affect any of the scientific conclusions derived by Savage et al. (2002) and Sembach et al. (2002b).

5. RESULTS

5.1. Detection Rate for Galactic O VI

We have detected Galactic O VI absorption along almost all of our sightlines. For the 26 objects with Q=4 the statistical error in the equivalent width lies between 6 and 15 mÅ. The Galactic O VI absorption is detected in every sightline with an S/N ratio greater than $7\sigma_{\rm W,stat}$ (the lowest value is 97±13 mÅ toward NGC 7469). The 23 objects with Q=3 have a statistical error between 14 and 25 mÅ, and O VI absorption is detected at at least the $6\sigma_{\rm W,stat}$ level toward each of these. The lowest value is 82±12 mÅ toward Mrk 1095.

At the Q=2 level (30 objects, statistical error 22–49 mÅ) Galactic O VI is detected above the $3\sigma_{\rm W,stat}$ level in 24 cases. The $2.8\sigma_{\rm W,stat}$ (75±27 mÅ) detection toward NGC 7714 appears real, but toward HE 0450−2958, NGC 588, NGC 595, PG 0052+251 and SBS 0335−052 we can only set $3\sigma_{\rm W,stat}$ upper limits of 126, 147, 126, 117 and 123 mÅ, respectively. However, in 3 sightlines with Q=4, 1 with Q=3 and 4 with Q=2 an equivalent width <125 mÅ is measured. Thus, although Galactic O VI may still be present in the three directions with upper limits, N(O VI) must be relatively low.

For the 23 objects with Q=1 the equivalent width statistical error is 29–65 mÅ. Galactic O VI is detected above the $3\sigma_{\rm W,stat}$ level in 16 of these. The $2.6\sigma_{\rm W,stat}$ detection toward Mrk 290 also appears real. The $2.5\sigma_{\rm W,stat}$ detection toward Mrk 771 is based on the O VI λ1037.617 line. For the remaining six objects (HE 1115−1735, HE 1326−0516, Mrk 205, Mrk 926, NGC 3504 and PG 2349-014) we can only set $3\sigma_{\rm W,stat}$ upper limits of 115, 174, 195, 216, 192 and 117 mÅ, respectively. Compared to the minimum values detected in the sightlines with Q=3 and Q=4, the limits for HE 1115−1735 and PG 2349−014 are still low enough that it is clear that W(O VI) must be relatively small. For the other four the error is so large that these non-detections are not really significant, as there are 30 directions toward which W(O VI)<200 mÅ.

Of the directions with clear detections, the ratio of the equivalent width to its systematic error is <4 in only six cases. In five of these (IRAS F11431−1810, MRC 2251−178, Mrk 501, Mrk 734 and NGC 7714, it is the velocity-limit error that dominates the systematic error, because the separation between the high-velocity and Milky Way absorption is not sharp. For UGC 12163 the equivalent width itself is rather low.

In summary, we clearly detect Galactic O VI in 91 out of 102 directions. For six of the directions yielding an upper limit N(O VI) must be low (<125 mÅ). Since there are eight sightlines with a significant detection where the equivalent width lies below 125 mÅ, slightly better data might yield detections. We thus conclude that O VI is present in basically all directions.

5.2. Detection Rate for High-Velocity O VI

High-velocity O VI with $|v_{\rm LSR}|$>100 km s^{-1} is found along many sightlines. Here, we discuss the detection rate as function of Q. Thirty five high-velocity components occur in 22 of the 26 sightlines with Q=4, with equivalent widths ranging from 14 to 200 mÅ. Only toward NGC 1068, PG 0804+761, VII Zw 118 and vZ 1128 is high-velocity O VI not found. Fourteen of these high-velocity O VI components have a relatively small systematic error (ratio of equivalent width to $\sigma_{\rm W,syst}$>3). Another 15 are clearly significant (ratio of equivalent width to statistical error >4), but with a relatively large systematic error (W/$\sigma_{\rm W,syst}$=1.2–3). The latter is usually dominated by uncertainties in the velocity limits of the integration, sometimes by the removal of the J=3 or 4 H_2 line(s). Since these components are clearly wider than a single resolution element and/or they form a clear wing that continues the Galactic absorption, they are therefore real, but difficult to measure accurately. Six components at high-positive velocities are both weak (14–37 mÅ, 2–3.5 $\sigma_{\rm W,stat}$) and have a large systematic error (toward 3C 273.0, H 1821+643, Mrk 421, Mrk 876, PG 1116+215 and PG 1259+593) and some of these components may not be real.

Seventeen high-velocity components occur in 12 of the 23 sightlines with Q=3, with equivalent widths ranging from 30 to 265 mÅ. Ten of these are both statistically highly significant and have a small systematic error (W/$\sigma_{\rm W,syst}$>3.0). Six are strong, but with a relatively large systematic error (W/$\sigma_{\rm W,syst}$=1.4–3.0), which is dominated by uncertainties in the integration limits. The 125 km s^{-1} component toward PG 1351+640 is weak (31±10 mÅ) and has a high systematic error (29 mÅ) because the lower velocity limit is rather uncertain; it is probably real, however.

Twenty high-velocity components occur in 14 of the 30 sightlines with Q=2, with equivalent widths ranging from 65 to 300 mÅ. All but three have W/$\sigma_{\rm W,stat}$>4, all have W/$\sigma_{\rm W,syst}$>1.4, and all appear real. The ones with the lowest ratio of W/$\sigma_{\rm W,syst}$ (Mrk 357, Mrk 734, Mrk 501, NGC 7714, PG 0052+251) are clearly present but hard to measure accurately because of H_2 contamination.

Thirteen high-velocity components occur in 11 of the 23 sightlines with Q=1, with equivalent widths ranging from 65 to 290 mÅ. Five of these are clearly significant – the ratios of both W/$\sigma_{\rm W,stat}$ and W/$\sigma_{\rm W,syst}$ are >4. Another four are clearly present (W/$\sigma_{\rm W,stat}$>3.5) but hard to measure because of uncertainties in the integration limits or the removal of H_2 contamination. Of the remaining five HVC components, one is strong (>100 mÅ) and clearly real (toward NGC 3991). The most negative-velocity HVC toward PG 2349−014 is weak, has low S/N and a large systematic error, mostly due to uncertainties in H_2 decontamination, but is probably real. The remaining two ccomponents (toward Mrk 106 and PG 1001+291) may not be real, however.

Table 3 lists the detection rate (number of components with W>3$\sigma_{\rm W,stat}$) of high-velocity O VI for different minimum relative systematic errors and different equivalent width limits. This table shows that for a given equivalent width limit the detection rate is quite constant as function of Q. Strong HVC absorption (EW>200 mÅ) occurs in 10% of the sightlines, whereas Galactic absorption of such strength occurs in 60% of the sightlines. And while 90% of the sightlines show Galactic absorption stronger than 65 mÅ (and O VI is likely to exist at this level in the eleven sightlines yielding an upper limit), only 47% of the sightlines have high-velocity O VI that strong. However, in the best quality (Q=3 and 4) spectra, the detection rate increases to 70% (12+22 out of 23+26) for an equivalent width limit of 30 mÅ. Even weaker components (down to 14 mÅ) are detected in five sightlines (3C 273.0, Mrk 817, Mrk 876, PG 1116+215 and PG 1259+593). However, for components this weak it is sometimes no longer clear whether they are real or whether they are a fixed-pattern noise feature. Nevertheless, there are 13 sightlines in which high-velocity O VI could have been detected at the 20 mÅ level (S/N>18 per resolution element), and it is found in 12 of these (92%). It is notable that the only one of these sightlines without a HVC is the direction toward vZ 1128, which is a star at z=9.5 kpc. This suggests that the high-velocity O VI may be distant.

In summary, it appears that the detection rate for high-velocity O VI strongly increases with the equivalent width limit. It may even reach 100% at a sufficiently low equivalent width limit (possibly ∼10 mÅ, or $\sim 8\times10^{12}$ cm^{-2}).

5.3. Velocity Distribution of O VI Components

In Fig. 9 we show the distribution of the central velocities of all measured components, including both the Galactic and the high-velocity O VI. The top panels plot the column density against the central velocity, and the b-value codes the size of the symbols. This shows that the average and minimum value of the thick disk absorption clearly are larger than those for the high-velocity absorption, but also there are many high-velocity components that are stronger than the Galactic absorption in some sightlines.

It is notable that the distribution of points between ±100 km s^{-1} is qualitatively different than that at higher velocities. This may be due to the blending of many weaker components in that velocity range; i.e. the Galactic absorption is probably not due to a single absorber, but to a mixture of several in the line of sight. This also implies that at low LSR velocities there probably are many hidden absorption components that are related to the same phenomenon that produces the high-velocity O VI.

The average column density of the Galactic O VI components is 14.33±0.20 (the median is 14.36), while for the high-velocity O VI the average is 13.95±0.34 (with median 13.97). If the column density distribution of HVC components represents the real distribution of O VI clouds in the Milky Way, then on average the low-velocity absorption represents a mixture of two to three absorbing clouds in the sightline.

Figures 9b to f present the histograms of the distribution of the average velocity, $\bar{v}_{\rm obs}$, for several different equivalent width ranges. There does not appear to be a relation between the strength of the absorption and its velocity: both weak and strong high-velocity O VI occur at all velocities. Figures 9i to n present the same histograms, but concentrating on the Milky Way absorption. Again, there does not appear to be a correlation of strength with velocity, although in this case that was also not expected.

5.4. Detecting O VI in Local Group Galaxies?

For all Local Group galaxies in the list of Mateo (1998) we determined whether a sightline in our sample passes within 50 kpc of such a galaxy, giving the possibility of searching for O VI in its extended halo.

In the case of M 31, *FUSE* program Z002 (PI Wannier) aimed at observing several QSOs near it. These five sightlines (as well as HS 0035+4405) all pass within 60 kpc from M 31, but there is insufficient flux for all but one object (RX J0048.3+3941). The spectrum of the short (8.6 ks) observation of this faint object has low S/N ratio (2.3 per resolution element), and we did not include it in our sample. Nevertheless, we can see that the Milky Way absorption is weak, and that a very strong (300±80 mÅ) high-velocity feature is present at $v_{\rm LSR}$=$-$180 km s^{-1} (which is similar to the velocity of M 31). However, a high-negative velocity O VI component is seen in all directions in this part of the sky. Toward RX_J0048.3+3951 it is much stronger than most of the other such components, which typically are about 130 mÅ. Therefore, this component probably is a mixture of the extended O VI feature and absorption due to M 31. A longer observation of this QSO would clearly be useful.

Some of our sightlines also pass near one of the companions of M 31 (NGC 147, NGC 185, NGC 205, And I–VII, LGS 3). Since these are dwarf elliptical or dwarf spheroidal galaxies (diameter <1 kpc) without much gas, none of the sightlines in our sample come close enough to be interesting (the smallest impact parameter is 5.7 kpc).

Four of the objects in our sample are actually H II regions within M33 – NGC 588, NGC 595, NGC 592 and NGC 604. The flux we see is an amalgan of the continua of many O stars. Nine individual O stars inside M 33 were also observed by *FUSE* (PI Hutchings). Although each of these objects has a rather difficult continuum, very strong O VI absorption is seen in all sightlines at velocities of $-$200 km s^{-1}, and this absorption is probably associated with M 33. A future study of O VI in M 33 seems warranted.

There are four sightlines in our sample that pass within 150 kpc from M 33. The one with the smallest impact parameter (3C 48, 2°.6 or 38 kpc) is faint and the spectrum has low S/N ratio. A longer integration could be helpful. The sightlines toward Mrk 352, Mrk 357 and PG 0052+251 pass 7°.4 (90 kpc), 7°.9 (96 kpc) and 10°.9 (133 kpc), respectively, from the center of M 33. In all three, high-negative velocity O VI absorption is seen, just as is the case in all sightlines in this part of the sky. However, the rotation field of M 33 (e.g., Deul & van der Hulst 1987) is such that velocities near or above 0 km s^{-1} are expected at the positions of these background targets. No absorption is seen at such velocities down to 3σ limits of log N(O VI)=14.08, 13.90 and 13.95, respectively. Considering this, it appears that any extended O VI-containing halo around M 33 is smaller than 100 kpc.

A number of sightlines in our sample pass within 10 kpc from one of the nearby dwarf ellipticals and dwarf spheroidals in the northern sky. 3C 351.0 and PG 1626+554 lie $3\overset{\circ}{.}4$ and $7\overset{\circ}{.}6$ (5 and 10 kpc) from Draco (v=-293 km s^{-1}, distance d=82 kpc, full diameter as given in *NED* D=0.8 kpc). Mrk 876, Mrk 279 and PG 1351+640 pass $\sim$7° (8 kpc) from Ursa Minor (v=-248 km s^{-1}, d=66 kpc, D=0.5 kpc). In all these sightlines high-velocity O VI associated with complex C is seen, but none is detected at v<-200 km s^{-1}.

At l>180°, PG 1116+215 lies $1\overset{\circ}{.}6$ (5.6 kpc) from Leo II (v=75 km s^{-1}, d=205 kpc, D=0.7 kpc) and NGC 3115 lies $6\overset{\circ}{.}4$ (10 kpc) from Sextans (v=227 km s^{-1}, d=86 kpc, D=0.9 kpc). The smallest impact parameter is found for PG 1004+130, which lies $0\overset{\circ}{.}6$ (2.5 kpc) from Leo I (v=290 km s^{-1}, d=250 kpc, D=0.6 kpc). However, in this sightline there is an absorption feature at velocities between 100 and 400 km s^{-1} that is probably intrinsic O III λ832.927, which hides any weak O VI associated with Leo I.

Near Leo A (v=25 km s^{-1}, d=690 kpc, D=1.0 kpc) lie the sightlines to 3C 232 ($1\overset{\circ}{.}7$, 20 kpc), PG 1001+291 ($2\overset{\circ}{.}1$, 25 kpc) and PG 0946+301 ($2\overset{\circ}{.}2$, 27 kpc). None of these three objects allow a determination of whether this dwarf irregular has an extended O VI halo. First, not only is 3C 232 very faint, it also samples the halo of NGC 3067, and the O VI line is confused by Lyβ absorption associated with NGC 3067. PG 0946+301 just is too faint. PG 1001+291 could in principle be useful. However, the velocity of Leo A is too low to separate any absorption from a Leo A halo from that due to the Milky Way, and the low-velocity O VI absorption toward PG 1001+291 is not unusually strong.

Impact parameters for the more distant (d=1.2–1.6 Mpc) irregulars in the northern sky are generally >50 kpc. Among UGCA 92, Sextans A, Sextans B, Antlia, NGC 3109 and GR 8 the smallest impact parameter is 25 kpc (PG 1004+054 lies $1\overset{\circ}{.}1$ from Sextans B). In any case, no matching lines of O VI were found.

There are three nearby dwarf ellipticals in the southern sky. PKS 0558$-$504 lies $6\overset{\circ}{.}6$ (12 kpc) from Carina (v=224 km s^{-1}, d=100 kpc, D=0.6 kpc). A high-velocity O VI component is seen in the spectrum of PKS 0558$-$504, at 260 km s^{-1}, but it is more likely that this is associated with the small high-positive velocity HVCs nearby, which may be flecks of the Magellanic Stream. HE 0226$-$4110 lies $6\overset{\circ}{.}9$ (17 kpc) from Fornax (v=53 km s^{-1}, d=138 kpc, D=0.6 kpc) and Ton S210 lies $7\overset{\circ}{.}1$ (10 kpc) from Sculptor (v=108 km s^{-1}, d=79 kpc, D=0.8 kpc). The velocities of these dwarfs are too small – any associated absorption component would be hidden by the Galactic absorption.

Eight dwarf irregulars with distances 0.4–1.3 Mpc lie in the region where high negative-velocity O VI at $v$$\sim$$-300$ and $\sim$$-180$ km s^{-1} is always seen: NGC 6822 (v=-53 km s^{-1}), IC 10 (v=-344 km s^{-1}), IC 1613 (v=-237 km s^{-1}), UGCA 438 (v=62 km s^{-1}), DDO 210 (v=-137 km s^{-1}), Pegasus (v=-182 km s^{-1}), SagDIG (v=-75 km s^{-1}) and WLM (v=-123 km s^{-1}), Only the sightline toward Mrk 509 passes less than 50 kpc from one of these (31 kpc from DDO 210). It is notable that many of the dwarf irregulars have v between -100 and -350 km s^{-1} and that they are found in the same region of the sky where high-negative velocity O VI is prevalent.

Four more distant (d=0.4-1.6 Mpc) galaxies lie at l>270°, b<0° (Phoenix, Tucana, NGC 55 and IC 5152). However, this region of the sky is poorly sampled in our survey.

5.5. Channel Maps

5.5.1. Construction of Channel Maps

In this subsection we present maps of the O VI column density. Savage et al. (2002) and Sembach et al. (2002b) show the total column density maps for the Galactic and high-velocity components. Here (Fig. 10), we show a series of maps created by calculating the O VI column density in fixed, narrow velocity ranges relative to the Local Standard of Rest (LSR). These maps are constructed by stepping through galactic longitude and latitude, and determining which object lies closest to each selected position. A value is then chosen from a gaussian distribution that is centered on the column density toward that closest sightline and has a dispersion equal to the 1-σ measurement error. The resulting column density determines the color of the pixel, as coded by the wedge below the plot. If no object lies within 12° from the tested position, no assignment is made. For an accurately measured value, the color is almost the same across the whole 12° radius patch, but for values with relatively large errors a strong mottling effect can be seen.

The velocity channels are 50 $\mathrm{km\,s^{-1}}$ wide between $\pm$200 $\mathrm{km\,s^{-1}}$, but a wider range (100 $\mathrm{km\,s^{-1}}$) was used from $\pm$(200–300) $\mathrm{km\,s^{-1}}$ because there is much less O VI at these velocities. The two edge channels are even wider ($\pm$(300–500) $\mathrm{km\,s^{-1}}$). No integration was done outside the velocity limits where we deemed O VI to be present. For example, if we had previously determined that the sightline showed O VI between -85 and 45 $\mathrm{km\,s^{-1}}$, we integrated from -85 to -50, -50 to 0 and 0 to 45 $\mathrm{km\,s^{-1}}$. We also calculated the error in each of these channels, and we only included the sightline in the channel map if the ratio of the resulting column density in the channel to its statistical error is $>$2. For the sightlines with Q=4, significant upper limits can be set (2σ limit for log N(O VI) $<$13.20). To indicate these, we calculated the typical error in a 50 $\mathrm{km\,s^{-1}}$ wide bin, and then drew a small patch (2.°5 radius) around these sightlines with a color corresponding to the 2σ level. No integrations were done in the $\pm$100 $\mathrm{km\,s^{-1}}$ velocity range for the eleven sightlines where we deemed the low-velocity measurement to be just an upper limit.

The figure captions list the number of sightlines for which O VI is detected in absorption in each of the channels. This shows that the number of sightlines in a channel is about the same as the number in the channel with opposite sign, i.e. the velocity distribution of the O VI is rather symmetric. The 0 to 50 $\mathrm{km\,s^{-1}}$ channel (Fig. 10g) shows the source identifications. To help in understanding the content of these maps Fig. 11 shows a map of the velocity field of the H I high-velocity clouds.

5.5.2. Results – Milky Way

The four channels between velocities of -100 and 100 $\mathrm{km\,s^{-1}}$ show the O VI associated with the Milky Way (Fig. 10e–h). It is obvious that this gas is widespread, and that it occurs at all of these velocities in almost all directions. By comparing the maps centered at v_{LSR}=$\pm$75 $\mathrm{km\,s^{-1}}$ (Figs. 10e and h), the imprint of Galactic differential rotation can be discerned in the northern sky. At -75 $\mathrm{km\,s^{-1}}$ the column densities are higher at l<180° than at l>180°, while at 75 $\mathrm{km\,s^{-1}}$ the opposite is the case. In the southern sky this effect is not as visible. This may be partly due to the fact that the region $l<180°$, $b<0°$ has low total O VI column density.

5.5.3. Results – High-Negative Velocity Gas

The channel maps show that the O VI at the highest negative velocities is concentrated in the southern half of the first quadrant, or more precisely, in the region l=20°–140°, $b<-30°$. In the velocity ranges −500 to −300 and −300 to −200 km s^{-1} (Fig. 10a, b) the O VI column density in this part of the sky is considerable – about 10^{14} cm^{-2}. The many upper limits of log N(O VI)<13.20 show that elsewhere in the sky O VI with such velocities could have been detected, but was not. A remarkable property of the O VI in this octant is that in most directions there are two components with high-negative velocity, one near ∼−300 km s^{-1}, and one with lower velocities, typically ∼−150 km s^{-1}. These may or may not represent different phenomena. Figure 11 of Sembach et al. (2002b) shows the map of the central velocities of the high-velocity O VI, overlaid on the H I HVC, clearly showing the two negative-velocity components.

In the same region of the sky, the H I map (Fig. 11) shows the presence of the very-high-velocity clouds (VHVCs), which have velocities up to −465 km s^{-1}. These clouds are usually rather small. None of the sightlines in our sample passes through a neutral VHVC, although some come within a few degrees. It is possible that the VHVCs and the high-velocity O VI are somehow related, but more data is needed to investigate this. It would be useful to obtain O VI column densities in the region of the Anti-Center HVCs (l=150° to 200°, b=−45° to 0°), but unfortunately the extinction in this part of the sky is high because of nearby star-forming complexes, and no sufficiently bright extragalactic targets are known.

A possible explanation for the high-negative velocity component of the O VI sky is that this gas is related in some fashion to the Local Group. The main concentration of Local Group galaxies is in the region l=100°–150°, b=−60°–0°, and these galaxies all have negative velocities. The high-negative velocity O VI is also seen in the directions near and in M 31 and M 33, where it blends with the absorption due to those galaxies. However, a more detailed analysis is required to determine the origin of the high-negative velocity O VI; see Sembach et al. (2002b).

5.5.4. Results - Magellanic Stream

The region of sky where the high-negative velocity O VI occurs is the same region where the H I velocities of the Magellanic Stream reach values between −300 and −400 km s^{-1}. However, the Magellanic Stream is a rather long, narrow (∼5°–10°) feature at l=90° (see Fig. 11). At negative velocities, only three sightlines intersect the Stream's H I (NGC 7469, NGC 7714 and PG 2349−014). Tidal models for the Stream (Gardiner & Noguchi 1996) predict that it fans out to about the l=80°–110° region at b∼−30°. The prediction for the velocities being <−300 km s^{-1} is fairly robust. However, to produce high-negative velocity gas over the wide area that it is detected in O VI, these models would need to be fundamentally changed. Still, some of the gas in the more negative of the two high-negative velocity O VI components can be made to fit within the tidal models. For the O VI component near −150 km s^{-1}, however, the 200 km s^{-1} discrepancy implies that it is probably unrelated to the Stream.

At positive velocities only one sightline intersects the H I part of the Stream (Fairall 9), while several other pass close by (HE 0226−4110, NGC 1705 and PKS 0558−304). In each of these high-positive velocity O VI absorption can be seen with velocities similar to that of the H I. This suggests that the Stream has an extended hot envelope.

5.5.5. Results – Complex C

In the −200 to −100 km s^{-1} velocity range, O VI associated with HVC complex C can clearly be discerned in the northern sky (compare the region around l=100°, b=45° in Figs. 10d and 10e with Fig. 11). This HVC has a low metallicity (∼0.1 solar, see Wakker et al. 1999, Richter et al. 2001b, Gibson et al. 2001), and seems to be a tidally-stretched cloud that is falling toward the Milky Way.

Complex C is seen in H I emission in nine sightlines (Mrk 279, Mrk 290, Mrk 501, Mrk 506, Mrk 817, Mrk 876, PG 1259+593, PG 1351+640 and PG 1626+554). In five of these O VI is detected in the −200 to −150 km s^{-1} channel. One (PG 1259+593) gives an upper limit of 12.95 in this channel. Strong absorption is seen in all nine sightlines in the −150 to −100 km s^{-1} channel. The strong absorption toward H 1821+643 in the −300 to −200 km s^{-1} channel may also be related. That toward PG 1626+554 in this channel appears to be strong, but is only a 2.5σ detection.

In the −200 to −150 km s^{-1} channel, no O VI absorption is seen in sightlines adjacent to complex C (except for a 4.5σ detection in the wing of the profile toward NGC 3310). In the lower-velocity channel (−150 to −100 km s^{-1}), weak O VI is seen in many directions (PG 0804+761, Mrk 116, PG 0953+414, Mrk 421, Mrk 209 and Mrk 478), but this is just the negative-velocity tail of the Galactic absorption. A stronger component occurs toward Mrk 106, but this sightline also crosses HVC complex A. Strong O VI further occurs toward H 1821+643 and 3C 382, but for these low-latitude sightlines we conclude that the O VI is associated with the Outer Arm. Only toward NGC 3310 is N(O VI) high even though no high-velocity H I is detected.

Weak absorption in the direction of complex C also appears in the 100 to 150 km s^{-1} channel. This component can clearly be discerned in the spectra of Mrk 817, PG 1351+640 and PG 1626+554 as an extended wing. Toward Mrk 876 and PG 1259+593 a weak extended wing is also detected, but it is less than 2σ if integrated only in the 100 to 150 km s^{-1} velocity range.

Sembach et al. (2002b) discuss the significance of the detection of O VI associated with complex C.

5.5.6. Results – High-Positive Velocity O VI

In all high-positive-velocity channel maps, there is much O VI in the northern third quadrant (l=240°–300°, b>30°). This O VI extends to much higher latitudes than the high-positive velocity gas seen in H I, which is concentrated at b<30° (see Fig. 11). Only one of our sightlines samples such low latitudes (ESO 265−G23). Although it is a Q=1 object, the presence of strong high-velocity O VI is clear.

In many cases the high-positive velocity O VI manifests as an extended wing, while in some it is clearly separated from the Galactic absorption. For the case of 3C 273.0 (l,b=290°,65°) Sembach et al. (2001b) suggested that it represents outflowing material, as would be expected in the Galactic Fountain picture; however, this sightline shows one of the weakest positive-velocity wings. It is also possible that this gas is related to the Magellanic Stream, for which models (Gardiner & Noguchi 1996) predict that the most accelerated gas lies in the region (l,b∼270°,60°), i.e. in the extension of the high-positive velocity gas seen in H I. Other interpretations are also possible, such as that this gas represents distant Local Group material falling toward the Local Group barycenter. Sembach et al. (2002b) analyze each of these possibilities.

For two of the four sightlines with O VI at v>300 km s^{-1} (Mrk 478 and NGC 4670) it is likely that the absorption occurs in intergalactic gas, as these components are relatively narrow (b-values ∼30 km s^{-1}) and isolated in velocity and position.

6. CONCLUSIONS

We have presented information on a sample of 217 extragalactic objects and two distant halo stars observed with *FUSE*. We describe the process of calibration, the alignment of the O VI absorption lines and the construction of final spectra. Most of the extragalactic objects are quasars and Seyfert galaxies with relatively flat spectra, but some are nearby starburst galaxies. We fitted continua to these spectra, and identified the contamination of the O VI λ1031.926 line by two H_2 lines, by absorption intrinsic to the background target, and by intergalactic gas. Of the original sample of 219 objects, 2 guest observer objects were excluded because of overlapping science goals, 98 objects were too faint to measure Galactic O VI, and in 17 Galactic O VI is contaminated by other absorption, leaving us with a sample of 102 objects. For these we separated low and high-velocity O VI absorption, measured the O VI equivalent widths and column densities and studied the distribution of the errors. We reach the following conclusions:

1) To align *FUSE* spectra, it is necessary to use H I 21-cm emission spectra in the target direction in order to determine the velocity of the peak absorption as the H I does not always peak at 0 km s^{-1} – it may peak at any velocity between ∼−60 and 20 km s^{-1}. Further, when using v1.8.7 of the calibration pipeline, the *FUSE* wavelength scale appears to have shifts of up to ∼10 km s^{-1} between different regions of the same spectrum, so that it is necessary to align each absorption line individually. The wavelength calibration of v2.0.5 of the pipeline is much better, but we conclude that a comparison with H I data is still necessary, and even then there may still be offsets up to 10 km s^{-1}, due to both the intrinsic accuracy and the possibility that the gas sampled by a broad H I beam may differ from that in the narrow pencil beam toward the background target.

2) For bright objects (flux >8×10^{-14} erg cm^{-2} s^{-1} Å^{-1}) *FUSE* can obtain good spectra (Q>=3, S/N>9 per resolution element) in 15 ks. At flux levels of 4×10^{-14} erg cm^{-2} s^{-1} Å^{-1} this requires 20 ks, while Q=2 (S/N=5) requires only 6 ks. For objects with a flux of 2×10^{-14} erg cm^{-2} s^{-1} Å^{-1}, a 10 ks integration time is needed to obtain a spectrum with Q=2 (S/N=5), from which reasonable O VI information can be extracted after binning to 10 pixels, while good spectra (Q>=3, S/N>9)

require an exposure time >30 ks. For faint objects (flux $\sim 10^{-14}$ erg cm^{-2} s^{-1} Å^{-1}) the minimum exposure time for detecting O VI at Q>=1 (S/N>3) is 10 ks, while Q>=2 (S/N>5) requires 25 ks or more and Q>=3 (S/N>9 per resolution element) requires >80 ks. For fainter objects even very long observations do not easily yield good spectra, because the background uncertainties start playing a role. The highest S/N ratio that has been achieved is ∼30 per resolution element, both for a very bright object (vZ 1128, flux 60×10^{-14} erg cm^{-2} s^{-1} Å^{-1}, 31 ks) and a rather faint object (PG 1259+593, flux 1.8×10^{-14} erg cm^{-2} s^{-1} Å^{-1}, 633 ks).

3) Galactic H_2 in the J=0 and J=1 states is detected in 80% of the 102 directions with spectra of quality 1–4. The 19 non-detections cluster in the regions l=0–120°, b>40°, l=210–60°, b<−40°. The upper limit on $N(H_2)$ can be as low as 10^{14} cm^{-2} in each rotational level. In 62 out of 102 sightlines, lines of J=3 or higher are detected. H_2 turns out to be ubiquitous in intermediate-velocity clouds. We analyze this in a separate paper (Richter et al. 2002). In 23 cases H_2 contaminates the O VI absorption profile, but we can correct for it in all but one case (NGC 3783).

4) Contamination by intrinsic or intergalactic absorption occurs occasionally. In 16 sightlines this makes it impossible to measure the Galactic O VI absorption.

5) The Galactic O VI, which we also refer to as "thick disk" absorption, may extend as far −145 or 140 km s^{-1} (Fig. 5), but in 88 sightlines it is confined to within ±120 km s^{-1} and in 61 to within ±100 km s^{-1}. The average negative velocity limit is −90 km s^{-1}, while the average positive velocity limit is 90 km s^{-1}.

6) We present measurements of the O VI equivalent widths in the Galactic and high-velocity components, and calculate five contributions to the error: one associated with the random noise fluctuations in the spectrum, one associated with continuum fitting (placement), a fixed-pattern noise contribution, an error associated with the choice of integration range, and an error related to uncertainties in the determination of the parameters of contaminating H_2 lines. The first two are combined into a statistical error, while the latter three give a systematic error. Comparing two methods of determining the error associated with the placement of the continuum (Fig. 7) shows that the ±rms/3 method of estimating continuum errors tends to overestimate these for flat continua, but gives reasonable answers for continua fit with a second-order polynomial.

7) In the subsample of 20 sightlines where it is possible to compare the apparent optical depth profiles of the O VI λ1031.926 and O VI λ1037.617 lines (Fig. 8), we find 17 components for which the O VI absorption is not saturated, since the ratio of column densities is unity, to within the 1σ error. Of the remaining five components, minor saturation (ratio ∼1.2) may occur in four, while clear saturation (ratio ∼1.6) occurs in only one (Mrk 421). From this we conclude that integration of the apparent optical depth profile of the O VI λ1031.926 line will yield a reliable column density in almost all cases, and will still be correct to within 30% in the maybe 5 total sightlines where some saturation occurs.

8) We clearly detect Galactic O VI λ1031.926 absorption in 91 out of 102 directions. In eleven directions we can only set an upper limit, and for five of these N(O VI) must be relatively low. With even slightly more sensitive data O VI would probably have been found in the directions for which we now derive non-detections. The largest O VI equivalent width found is 429±12 mÅ, toward

PKS 2005−489, while the lowest detected equivalent width is about 80 mÅ (toward Mrk 1095 and NGC 7714).

9) High-velocity O VI λ1031.926 absorption stronger than 65 mÅ is detected in 48 of the 102 sightlines (47%) while high-velocity absorption stronger than 30 mÅ is found in 34 of the 49 sightlines with Q=3 or 4 (69%). In 13 sightlines a high-velocity feature as small as 20 mÅ could have been detected, and it is found in 12 of these (92%).

10) We show that both weak and strong high-velocity O VI absorption components occur at all velocities in the ranges $\sim$−400 to −100 and 100 to 400 km s^{-1} (Fig. 9). The scatter plot of column density against velocity suggests that many absorbers similar to those seen at high-velocity may be blended with the Galactic absorption.

11) We checked the sightlines that pass within a few degrees of Local Group galaxies. None of the dwarf irregulars, ellipticals and spheroidals appear to show associated O VI, nor was any expected because of the small sizes of these galaxies. Four sightlines are toward H II regions in M 33. Since several M 33 OB stars have also been observed, it should be possible to study O VI in M 33. Similarly, several M 31 OB stars have been observed. One QSO near M 31 is bright enough that an improved spectrum is possible. However, a study of O VI in M 31 and M 33 is complicated by the fact that high-negative velocity O VI absorption (at velocities expected for O VI in those two galaxies) is present over a large part of the southern sky.

12) For the case of M 33, its rotation curve predicts gas velocities near 0 km s^{-1} or larger along the sightlines to Mrk 352, Mrk 357 and PG 0052+251, which pass 90, 96 and 133 kpc from M 33, respectively. No such absorption is seen, limiting the extent of an O VI halo around M 33 to be <100 kpc, at a 3σ detection limit of log N(O VI)$\sim$14.0.

13) A series of O VI channel maps shows the imprint of differential Galactic rotation on the low-velocity absorption: in the −100 to −50 km s^{-1} channel, N(O VI) is larger at longitudes <180°, while in the 50 to 100 km s^{-1} channel it is larger at longitudes >180°.

14) The −200 to −100 km s^{-1} O VI channel maps show that the HVC complex C is clearly detected in O VI absorption. The positive-velocity side of the Magellanic Stream ($l$$\sim$270°) is detected in the 150 to 300 km s^{-1} channels although there is only one sightline where both H I and O VI are seen (Fairall 9). In all directions in the region l=20°–150°, b<−30° O VI is detected at high negative velocities <−200 km s^{-1}, while elsewhere in the sky only upper limits can be set. Conversely, in the 150 to 300 km s^{-1} channels high-positive velocity O VI is common in the region l=180°–300°, b>20°, and only upper limits are set elsewhere in the sky.

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APPENDIX

In this appendix we give notes for all 119 objects for which spectral lines are shown in Fig. 1. All of these have a spectrum with a signal-to-noise ratio >3 per resolution element near 1030 Å. These notes contain remarks on special things to be aware of concerning the separation between the Milky Way and high-velocity O VI, concerning H_2 contamination, as well as details about the nearby galaxy groups intersected and any other special features.

Reference is often made to galaxy groupings from Tully's (1988) catalogue. This catalogue gives the distance for each galaxy (based on direct determinations), its radial velocity and group membership. These distances are used to calculate the impact parameter of each target sightline from the angular distance between the sightline and the galaxy. All galaxies with an impact parameter of <200 kpc are explicitly mentioned. The correlation with galaxy groups was done in order to identify possible contaminating intergalactic Lyβ absorption (see Sect. 3.10). Where necessary, we give the name of the galaxy groupings according to Tully (1988), followed by the average velocity and velocity dispersion of the galaxies in the grouping.

3C 48.0

This sightline passes just 32 kpc from M 33, and 164 kpc from M 31. However, the source is too faint (0.5×10^{-14} erg cm^{-2} s^{-1} Å^{-1}) to have sufficient S/N ratio (1.3 per resolution element) after just 8.5 ks of integration. A longer observation might reveal associated absorption. If present, such associated absorption is expected at a velocity of -300 km s^{-1}, considering the H I velocity field of M 33 (Deul & van der Hulst 1987).

3C 232

This sightline passes through the halo of NGC 3067, 10 kpc from its center. A clear Lyβ line is seen at 1525 km s^{-1}, as is redshifted C II absorption, even though the S/N is only 1.5 per resolution element.

3C 249.1

The LiF2B channel of the second observation (P1071602) has no signal and thus was not used. The sightline lies just 3° from the edge of complex C as seen in H I, yet the O VI absorption only extends out to -75 km s^{-1}.

This sightline passes through the Ursa Major Galaxy Grouping (v=1360±540 km s^{-1}) and the Canes Venatici Galaxy Grouping (v=2360±330 km s^{-1}), as well as the GH64 (v=1480 km s^{-1}) and GH69 (v=3000 km s^{-1}) groups. It lies 1°.1 (600 kpc impact parameter) from NGC 3329 (v=2056 km s^{-1}), and 2°.4 (55 kpc impact parameter) from UGC6456 (v=96 km s^{-1}, R=0.6 kpc), but no intergalactic Lyβ can be discerned near O VI. Lyα is also absent at those velocities (Savage et al. 2000).

3C 273.0

This is among the 10 sightlines with the highest S/N ratio (28 per resolution element). A detailed investigation of this QSO was presented by Sembach et al. (2001b). The velocity scale preferred here differs by 9 km s^{-1} from that adopted by Sembach et al. (2001); see Sect. 3.4 for a discussion of this. Sembach et al. (2001b) report the same equivalent widths (within the errors), except that they include the 125 km s^{-1} component into the Milky Way component, and they did not split the error into a statistical and systematic component. The relatively large systematic error in the equivalent width of this component is due to uncertain integration limits.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range −70 to 105 km s^{-1} the ratio N(1037)/N(1031) is 1.13±0.04, suggesting that there might be some slight saturation.

Two H_2 components are clearly visible in the J=0, 1, 2 and 3 lines, but for J=4 only one component is seen. The strongest H_2 component is associated with the weak H I at 25 km s^{-1} (see Richter et al. 2002). This H_2 line has only a minor influence on the systematic error of the thick disk and HVC O VI components.

The features at 1029.161 Å and 1031.186 Å are Lyβ at z=0.00335 (v=1005 km s^{-1}) and z=0.00532 (v=1595 km s^{-1}), which are associated with the Virgo Cluster (Sembach et al. 2001). There are three small (diameter <10 kpc) galaxies in this cluster with impact parameter <300 kpc (NGC 4420, UGC 7612, and UGC 7512). The feature at 1035.445 Å is O VI in the Virgo cluster, at v=1020 km s^{-1}. The corresponding O VI λ1037.617 feature is blended with low-velocity H_2 J=3.

3C 351.0

There is a Lyman limit system at z=0.22 in this sightline, which blocks out all emission below 1112 Å. The sightline also passes just 6 kpc from the Draco dwarf spheroidal (diameter 1.8 kpc), but if there had been flux at 1030 Å any absorption associated with that galaxy (v=−30 km s^{-1}) would be confused with that in the Milky Way.

3C 382.0

This is one of three low-latitude sightlines in the sample toward which H I associated with the Outer Arm is seen (e.g., Habing 1966; Kepner 1970; Hulsbosch & Wakker 1988; Haud 1992). O VI is seen at corresponding velocities, extending to −130 km s^{-1}. The O VI measurement for the thick disk includes this component. A separate measurement is also given for the velocity range over which Outer Arm H I is seen.

The feature at 1033.650 Å (500 km s^{-1} on the O VI velocity scale) is intrinsic C III – the corresponding Lyβ, Lyγ and Lyδ lines are also seen. The features at 1033.090 Å and 1035.020 Å (340 km s^{-1} and 900 km s^{-1} on the O VI velocity scale) remain unidentified. There are no intrinsic Lyman lines at these velocities. Although there are no known galaxy groups in this low-latitude (high extinction) direction, these features may be Lyβ at v=2155 km s^{-1} and 2715 km s^{-1}. Unfortunately, the other Lyman lines are then in a part of the spectrum that is too noisy to confirm this, and no Lyα data are available.

ESO 141−G55

The HVC component in this spectrum is similar to the one seen in the nearby sightline toward PKS 2005−489 (12° away).

The H_2 J=4 line somewhat confuses the measurement of the O VI HVC component, but it only increases the systematic error from 12 to 15 mÅ.

The sightline goes through the middle of the Telescopium-Grus Galaxy Grouping (v=2030±500 km s^{-1}), and several galaxies lie within a few degrees (impact parameters 0.8–3 Mpc). No associated Lyβ absorption can be seen, however. The high-velocity O VI component at 175 km s^{-1} cannot be Lyβ, as the corresponding 200 mÅ Lyα line at 1223.72 Å is not visible in the *GHRS* spectrum of this object.

ESO 265−G23

This spectrum has low signal-to-noise ratio (3.2 per resolution element), but the thick disk O VI as well as the HVC O VI at 260 km s^{-1} are strong enough to measure with confidence. Less than one degree away lies a large H I cloud with velocities centered near 260 km s^{-1}, which is part of the leading arm of the Magellanic Stream. After the cutoff date for our sample, new guest observer data were obtained, increasing the exposure time from 5 to 45 ks. This shows that the HVC component extends only to ∼310 km s^{-1}, rather than the 345 km s^{-1} suggested by the earlier observation. We therefore only integrated between 200 and 310 km s^{-1}. HVC complex WD is present in this sightline at 120 km s^{-1}, but in this velocity range no strong O VI absorption is seen.

Intrinsic C III absorption (to go with the clearly detected intrinsic O VI and Lyγ) would overlap the H_2 λ1031.191 J=3 line, but does not appear to be present.

ESO 350−IG38 (Haro 11)

There is a broad absorption line near O VI λ1031.926, much of which is intrinsic S III λ1012.510 absorption between 5600 and 6250 km s^{-1}. In the same velocity range absorption is also seen in the O VI λ1031.926, C III λ977.020, N III λ989.799, C II λ1036.337, O I λ1039.230, Si II λ1020.699 and Lyman lines. It is thus impossible to extract the contribution of Galactic O VI from this spectrum.

ESO 572−G34

The O VI profile in this direction is unusual in that both the Milky Way and high-velocity components are very strong. Both are also clearly seen in the O VI λ1037.617 line. This sightline lies just a few degrees from IRAS F11431−1810 and HE 1115−1735, toward which the high-velocity O VI is also clearly seen.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range −70 to 100 km s^{-1} the ratio N(1037)/N(1031) is 0.94±0.16, while in the velocity range 100 to 240 km s^{-1} this ratio is 0.95±0.16.

ESO 572−G34 is part of the Crater Galaxy Grouping (v=1490±260 km s^{-1}) and has a systemic velocity of 1114 km s^{-1}. The galaxy's Lyβ absorption is clearly visible at 1029.3 Å. The sightline further passes just $0\overset{\circ}{.}3$ (114 kpc) from NGC 4027 (v=1460 km s^{-1}, R=24 kpc), but no absorption is seen at its velocity.

Fairall 9

This object is the only one in the sample that lies projected on the part of the H I Magellanic Stream where the Stream has positive velocities. Associated O VI absorption is clearly seen, but extends over a much wider velocity range than the H I. There is no clear separation between the O VI absorption associated with the Milky Way and with the Stream; 100 km s^{-1} was chosen as the separation velocity. No contaminating H_2 is present, since both the Milky Way and the Magellanic Stream H_2 absorption only show lines up to J=2.

The high-positive velocity absorption cannot be intergalactic Lyβ: no corresponding Lyα line is seen in the *GHRS* spectrum.

H 1821+643

This is one of three sightlines toward which the Outer Arm is seen in H I. C II, Si II and Fe II absorption at corresponding velocities is clearly present, extending to -160 km s^{-1}.

An earlier analysis of this sightline was presented by Oegerle et al. (2000), who already reported all the O VI components that we list.

A strong H_2 J=3 line makes the measurement of the high-negative velocity O VI absorption uncertain. The absorption depth of 7 other J=3 lines averages to 0.32±0.05, while the FWHM averages to 34±7 km s^{-1}. The velocity of the H_2 absorption is difficult to determine, but it clearly must be more positive than -10 km s^{-1}, the velocity of the peak H I emission. Using the best approximation to the H_2 J=3 absorption suggests that the absorption near -210 km s^{-1} is an about equal mixture of H_2 and O VI, and that there are two high-velocity O VI components. A very weak one (-260 km s^{-1}, W=21±7±17) mÅ ranges from -285 to -235 km s^{-1}, while a stronger one (-190 km s^{-1}, W=56±7±20) ranges from -225 to -160 km s^{-1}. The uncertain correction for H_2 is reflected in the large systematic error on the O VI components.

A further complication is the planetary nebula K1-16, which lies less than 1 arcmin away. The strong saturated components in the O VI λ1031.926 and O VI λ1037.617 lines near 10 km s^{-1} are very likely due to this object. The associated absorption was removed from the calculation of the Milky Way O VI equivalent width and column density.

HE 0226$-$4110

There are two observations for this object, the second of which was executed using a focal-plane split. I.e., the spectrum was placed at one of four different places on the detector during each of the 19 orbits. Fixed-pattern noise therefore was reduced by a factor 4.

The C II absorption does not reach zero flux, so there may be a small background offset that has not been calibrated out properly.

This is one of 3 sightlines where the thick disk O VI extends to more negative velocities than -120 km s^{-1} (to -140 km s^{-1}), but in which there is no convincing argument for measuring a separate high-velocity component.

There is absorption at a velocity of 165 km s^{-1} which probably is O VI, since there appears to be a counterpart in the O VI λ1037.617 line.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range -140 to 75 km s^{-1} the ratio N(1037)/N(1031) is 0.91±0.17.

The sightline passes just 12 kpc ($7'$) from the center of the Fornax dwarf spheroidal. However this galaxy is very small, having a diameter of just 0.5 kpc.

The sightline also lies about 8° from the main body of the Magellanic Stream, and just 3° from a small HVC with Stream-like velocities.

The feature at 1034.659 Å (795 km s^{-1} on the O VI velocity scale) may be intergalactic Lyβ, though there are no confirming observations of Lyα.

HE 0238$-$1904

The noisy nature of this spectrum makes it difficult to place the continuum and to determine the extent of the Galactic and HVC absorption. The feature at 1033.055 Å (330 km s^{-1} on the O VI velocity scale) is just 2.9σ, and is classified as "unidentified"; it may not be real. If it were O VI, the corresponding absorption in the O VI λ1037.617 line is confused with a H_2 line.

When discernable, the other H_2 J=3 lines in the spectrum all have a velocity of $\sim$0 km s^{-1}. The mismatch between the predicted H_2 λ1031.191 line and the observed feature is probably due to the emission-like feature in the LiF1A channel, which distorts the spectrum.

HE 0450−2958

The LiF1A channel appears to show a weak O VI line, but this is not confirmed in the (noisier) LiF2B channel. The combined spectrum has low S/N, but it is clear that the Milky Way O VI component is rather weak. In fact, only a 3σ upper limit of 115 mÅ or log N(O VI)<13.96 can be set.

The sightline goes through the Fornax-Eridanus Galaxy Grouping (v=1580±490 km s^{-1}) (d=17 Mpc); UGCA 95 and UGCA 97 (v=1290 km s^{-1}) lie $\sim$1° away (300 kpc impact parameter). It also passes through the Dorado Galaxy Grouping (v=970±250 km s^{-1}) (d=10 Mpc), and several galaxies have impact parameters of 450–800 kpc. However, no intergalactic Lyβ absorption can be discerned.

HE 1115−1735

The O VI column density is low (3σ upper limit of 105 mÅ or log N(O VI)<13.92), although this sightline is just a few degrees from IRAS F11431−1810 toward which Galactic O VI is very strong (294±22 mÅ). On the other hand, the HVC component is clearly present and about as strong as toward IRAS F11431−1810. There does not seem to be a contaminating J=4 H_2 line, since no other J=4 lines can be discerned.

HE 1228+0131

Toward this object there is strong Lyβ absorption at 1495, 1760 and 2335 km s^{-1}, associated with the Virgo Cluster. Lyα counterparts for both these lines are seen in the *STIS* spectrum of this object. The first 14 Lyman lines of this series can be clearly seen in the *FUSE* spectrum. The sightline passes within 300 kpc of a number of galaxies (NGC 4517, UGC 7685, NGC 4536).

The 1760 km s^{-1} absorption distorts Galactic O VI λ1031.926, although the positive-velocity wing (v$\sim$50–200 km s^{-1}) must be Galactic O VI. Unfortunately, the O VI λ1037.617 line can not be used as an alternative, since the contamination from H_2 J=1 cannot be determined; the apparent strengths of the 1037.146 and 1038.156 Å lines are inconsistent with each other and with other J=1 lines.

The nature of the feature at 1032.913 Å (290 km s^{-1} on the O VI velocity scale) is unclear. It is unlikely to be high-velocity O VI as there is no counterpart in the O VI λ1037.617 line. It cannot be Lyβ since no Lyα absorption is visible.

HE 1326−0516

Although the S/N ratio is low, the O VI column density clearly is low. In fact, only a 3σ upper limit of 175 mÅ (log N(O VI)<14.15) can be set.

HE 2347−4342

This object is very faint (10^{-15} erg cm^{-2} s^{-1} Å^{-1}), but the 704 ks exposure time (the longest done with *FUSE*) allows the detection of the redshifted He II forest (Kriss et al. 2001). This completely covers low-redshift absorption, however.

HS 0624+6907

The individual channels for the two observations are rather noisy and are not completely consistent. The Galactic absorption seems stronger in the two LiF2B channels than in the two LiF1A channels.

This is one of three sightlines toward which the Outer Arm is seen in H I emission (the other two are 3C 382.0 and H 1821+643). However, unlike in the other cases, there is no O VI absorption at the velocities of the Outer Arm. in this direction.

HS 1102+3441

This spectrum has one of the lowest S/N ratios in our final sample (3.4 per resolution element). Still, it clearly shows a blended thick disk and HVC O VI component. These were separated at a velocity of 95 km s^{-1}, where the absorption is minimal. In the O VI λ1037.617 line the HVC component is contaminated by a J=1 H_2 line. It is probably real, however, especially considering that in this part of the sky (l=180°–240°, b=45°–70°) many sightlines show absorption at high positive velocities.

The sightline passes through GH75 (v=1025 km s^{-1}), but no absorption is apparent at such velocities.

Note that *NED* gives the name PG 1102+347 for this source, but that there was no such object in the original PG catalogue (Green et al. 1986).

HS 1543+5921

This sightline passes 2″ (300 pc) from the dwarf galaxy SBS 1543+593 (v=2698 km s^{-1}, part of GH158). The flux of 0.75×10^{-14} erg cm^{-2} s^{-1} Å^{-1} (S/N ratio of 2 after the short 8.5 ks observation) is too low to detect Galactic O VI. Lyβ in SBS 1543+593 is clearly present, however, while any O VI in that galaxy is confused with geocoronal O I emission lines.

IRAS 09149−6206

In this sightline strong and broad (470 km s^{-1} wide) intrinsic O VI and C III lines can be discerned. Unfortunately, the C III overlies the positive-velocity wing of the Galactic O VI. It is not possible to determine how much it contaminates the Galactic O VI. We therefore did not include this sightline in our sample.

IRAS F11431−1810

The positive-velocity O VI absorption extends much farther than expected for Galactic absorption. The H_2 J=4 λ1032.356 line does not seem to be present, as no other J=4 lines can be seen. A choice was made to separate the thick disk and HVC components at a velocity of 100 km s^{-1}, which is the velocity at which a clearer separation is seen between thick disk and high-velocity O VI in two neighboring sightlines: ESO 572−G34 (3° away) and PG 1302−102 (21° away).

This sightline passes ∼2° (1 Mpc) from the Crater Galaxy Grouping (v=1490±260 km s^{-1}).

The galaxies in this small group that lie the closest to IRAS F11431−1810 have velocities of 1000 to 1620 km s^{-1}, so it is unlikely that some of the apparent Galactic O VI absorption is inter-group Lyβ. Unfortunately, the spectrum at 980 Å is too noisy to check for Lyγ and there are no HST spectra to check for Lyα.

MRC 2251−178

The O VI line in the LiF2B channel looks different from that in the LiF1A channel. There are two associated Lyγ absorption components (v=18550 and 18925 km s^{-1}), centered on 1032.710 and 1033.943 Å (230 and 585 km s^{-1} on the O VI velocity scale. These look smeared in the LiF2B channel. We therefore decided to use only LiF1A data for this object. This system has a velocity of −900 km s^{-1} relative to the nominal velocity of the AGN. There may be a foreground galaxy or associated foreground gas in the line of sight.

At first sight, the main Galactic absorption seems to extend to −145 km s^{-1} and to have two components. However, we note that toward other sightlines in this part of the sky (NGC 7469, NGC 7714, PHL 1811, PKS 2155−304) there is a separate component between −100 and −160 km s^{-1}, in addition to the high-negative velocity component at v<−200 km s^{-1}. In these sightlines the Galactic absorption usually extends only to about −70 km s^{-1}. Therefore, the absorption between −145 and −65 km s^{-1} was measured separately and considered a HVC component.

C II absorption is seen at a velocity of −250 km s^{-1}, with W=65±19 mÅ, or N(C II)$\sim 8\times10^{13}$ cm^{-2}. Assuming carbon is not depleted on dust, this corresponds to N(H I)=0.2×10^{17}/Z cm^{-2}, with Z the metallicity in solar units. The Green Bank spectrum sets a 3σ upper limit of $\sim 1\times10^{18}$ cm^{-2} on N(H I).

Mrk 9

For one of the three observations for this object, the detector high-voltage was off for 5 out of 8 orbits. The remaining 2.5 ks represent just 10% of the total integration time, and were discarded because they are difficult to align.

The Galactic O VI profile clearly shows two components, which is unusual.

This sightline crosses the edge of the Lynx Galaxy Grouping (v=1850±280 km s^{-1}), whose galaxies have velocities between 1380 and 2100 km s^{-1}, and lie in a horseshoe shape around the Mrk 9 sightline. The closest galaxies in the group (NGC 2460, v=1553 km s^{-1}; UGC 4093, v=1646 km s^{-1}; and UGC 3826, v=1847 km s^{-1}) lie 3° away (impact parameter ∼1.2 Mpc). The Lyβ absorption associated with this group would appear between v=−400 and 300 km s^{-1} on the O VI velocity scale; Lyα observations will be necessary to exclude the probability that any of the absorption in this velocity range is Lyβ.

Mrk 36 (Haro 4)

The feature at −278 km s^{-1} on the O VI velocity scale is the H_2 λ1031.191 line at −55 km s^{-1} in the IV-Arch (see Richter et al. 2002). Several other H_2 J=3 lines with similar strengths can be seen.

Mrk 36 lies in the Leo Spur (v=620±160 km s^{-1}), but the galaxies closest on the sky lie behind it.

Mrk 54

There is intrinsic O I λ988.773 and Si II λ989.873 absorption at approximately 1032.92 and 1034.26 Å (290 and 680 $\mathrm{km\,s^{-1}}$ on the O VI velocity scale). The wing of intrinsic O I may overlap Galactic O VI absorption, making both the continuum and the upper velocity limit too uncertain to measure Galactic O VI. We therefore did not include this object in our final sample.

Mrk 59

This object is a bright H II region representing the starburst in the galaxy NGC 4861 (v=847 $\mathrm{km\,s^{-1}}$).

Mrk 79

The first of the three observations of this object was marred by many detector burst events, but the O VI features are consistent with those in the second observation. During the third observation the high-voltage was off on side 1 for 5 of the 7 orbits; we did not include this observation in the final spectrum. In the final spectrum the continuum is difficult to determine, but because the O VI absorption is relatively strong, it is well-measured.

Mrk 106

This spectrum has low S/N (3.6 per resolution element after combining both LiF channels). The O VI absorption in the individual channels looks different, but the differences fall within the noise.

This is one of three sightlines projected on to HVC complex A. Possible associated absorption is seen between -150 and -100 $\mathrm{km\,s^{-1}}$, although it is only a 3σ feature and it does not overlap in velocity with the H I in complex A.

There clearly is low-velocity H_2 in the J=2 level, but none of the J=3 lines are visible, possibly because of the low S/N ratio.

The feature at 1033.918 Å (580 $\mathrm{km\,s^{-1}}$ on the O VI velocity scale) is most likely intergalactic Lyβ at v=2395 $\mathrm{km\,s^{-1}}$ that is associated with the Leo Galaxy Grouping (v=1390$\pm$390 $\mathrm{km\,s^{-1}}$). The closest galaxy in this group is UGCA 154 (v=2287 $\mathrm{km\,s^{-1}}$, 2° away, 1.2 Mpc impact parameter). The sightline also passes through the Leo Spur (v=620$\pm$160 $\mathrm{km\,s^{-1}}$) and GH44 (v=930 $\mathrm{km\,s^{-1}}$), but no Lyβ absorption can be seen around these velocities.

Mrk 116

The continuum near the O VI λ1031.926 line is somewhat difficult to determine, as the absorption lies in the shoulder of the Lyβ absorption associated with Mrk 116. The decision on where to place the continuum was helped by knowing the expected strength of the H_2 lines. This justifies placing the continuum fairly high.

The H_2 J=4 line contaminates the positive-velocity edge of the thick disk absorption, but it only increases the systematic error from 21 to 24 mÅ.

This is one of three sightlines projected onto HVC complex A. No obvious associated high-velocity feature is present in the combined spectrum.

Mrk 205

This spectrum had a high background and the flux calibration is therefore less reliable than usual. However, the central part of the C II λ1036.337 line lies at zero flux, as expected.

O VI is not detected, but because the spectrum is noisy, a 3σ upper limit of only 195 mÅ or log NO VI)<14.19 can be set.

The feature at 1030.276 Å (-480 km s^{-1} on the O VI velocity scale) is Lyβ in the halo of NGC 4319 at v=1330 km s^{-1}.

Mrk 209 (Haro 29)

There are two observations of this object. The individual LiF1A and LiF2B channels are rather noisy, and the O VI absorption features are slightly different. The combined spectrum is fairly good, however.

This is one of 2 sightlines where the thick disk O VI extends to more positive velocities than 120 km s^{-1} (to 130 km s^{-1}), but in which there is no argument for a separate high-velocity component.

The feature at 275 km s^{-1} is O VI absorption intrinsic to Mrk 209, which has v=281 km s^{-1}.

Mrk 279

This is among the 10 sightlines with the highest S/N ratio (27 per resolution element). The flux of Mrk 279 seems to vary over time. It was 11×10^{-14} erg cm^{-2} s^{-1} Å^{-1} on 1999 December 28, 9×10^{-14} erg cm^{-2} s^{-1} Å^{-1} on 2002 January 11 and 7×10^{-14} erg cm^{-2} s^{-1} Å^{-1} on 2002 January 28.

Mrk 279 is one of 9 sightlines in which O VI absorption associated with HVC complex C is seen. The HVC O VI and H I component overlap, although the H I profile is complicated, with two HVC, two IVC and four low-velocity components clearly identifiable (each can be followed to neighboring directions).

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range -80 to 100 km s^{-1} the ratio N(1037)/N(1031) is 1.08±0.09.

The sightline crosses through the middle of the Canes Venatici Galaxy Grouping (v=2360±330 km s^{-1}). The closest galaxy that is part of this group is Mrk 263 (v=1529 km s^{-1}), at a distance of 1°.8 (775 kpc impact parameter). No intergalactic Lyβ is apparent at these velocities. The *GHRS* spectrum of this object goes down to 1222.6 Å, whereas the possible Lyα line is expected at 1221.14 Å, so no check of Lyα is possible.

The Ursa Minor dwarf spheroidal (v=17 km s^{-1}, radius 1.4 kpc) lies 7°.3 away (13 kpc impact parameter), but any associated O VI would be hidden in the main Galactic absorption.

Mrk 290

Although this is a spectrum with low S/N, absorption associated with HVC complex C is clearly present at the 4.7σ level, extending over a velocity range similar to that of the H I. The Galactic and HVC component were separated at a velocity of -70 km s^{-1}, based on the appearance of the H I profile. There does not appear to be H_2 in the J=4 state, and the extended positive-velocity wing is more likely to be O VI. On the other hand, the negative-velocity edge of the HVC absorption is contaminated by H_2 J=3, but the amount of contamination is minor.

The sightline passes through the Canes Venatici Galaxy Grouping (v=2360±330 km s^{-1}) and GH152 (v=1050 km s^{-1}). NGC 5963 lies 1°.5 (350 kpc) away. No Lyβ can be seen near these velocities, however.

Mrk 304

The positive-velocity edge of the high-negative velocity O VI component is contaminated by the H_2 J=3 line. This increases the systematic error from 38 to 46 mÅ.

The features at 1033.564 Å and 1034.000 Å (475 and 605 km s^{-1} on the O VI velocity scale) may be Lyβ at 2290 and 2420 km s^{-1}, though no other Lyman lines are seen. No *GHRS* or *STIS* spectrum exists that allows a check. The sightline passes through the middle of the Pegasus Galaxy Grouping (v=2170±480 km s^{-1}). The nearest two galaxies in this group (NGC 7280, v=2090 km s^{-1} and UGCA 429, v=2158 km s^{-1}) lie 3 degrees away (1.4 Mpc impact parameter).

Mrk 335

The high-negative velocity O VI component centered at −305 km s^{-1} is clearly present, as is the secondary component just to the side of the H_2 λ1031.191 line. Because the parameters of the H_2 line are uncertain, the systematic error on the equivalent width and column density of the high-negative velocity components reflects a possible variation from 25 to 35 km s^{-1} in the width, from −20 to 0 km s^{-1} in the velocity as well as a ±20% amplitude variation. This increases the systematic error from ∼8 to ∼20 mÅ.

The separation between the HVC and Galactic absorption is based on the fact that in most nearby sightlines Galactic absorption extends to about −75 km s^{-1} (see Sect. 4.1.3 point d).

The absorption at 1032.446 Å (150 km s^{-1} on the O VI velocity scale; W=47±8 mÅ) is intergalactic Lyβ at v=1965 km s^{-1}. Its Lyα counterpart can be found in the *GHRS* spectrum of Mrk 335 and was listed by Penton et al. (2000) as a feature at v=1965 km s^{-1} with W=229±30 mÅ. A second Lyα feature at 2290 km s^{-1} is too weak to have a detectable Lyβ counterpart. The sightline to Mrk 335 passes through the edge of the Pegasus Galaxy Grouping (v=2170±480 km s^{-1}), which corresponds to GH175. The nearest galaxies in this group (NGC 7817, v=2532 km s^{-1} and NGC 7798, v=2621 km s^{-1}) lie 0.°8 and 1.°7 away (impact parameters 430 and 970 kpc). The Lyα and Lyβ absorption lines are probably associated with this galaxy group.

The weak features at 1028.659 Å and 1034.897 Å (−950 and 865 km s^{-1} on the O VI velocity scale; 20±7 and 15±5 mÅ, respectively) may be Lyβ and O VI λ1031.926 at 865 km s^{-1}, associated with the Pegasus Spur (v=1110±260 km s^{-1}). The corresponding Lyα lies outside the wavelength range of the *GHRS* spectrum, which goes down to v(Lyα)=1420 km s^{-1}. The resolution of the *FOS* spectrum of this object is insufficient to separate Galactic Lyα and geocoronal Lyα from the probable Lyα at 865 km s^{-1}.

Mrk 352

Side 2 was misaligned in this early observation, so only LiF1A was used to measure O VI.

The H_2 J=3 line strongly contaminates the O VI HVC components. Its presence increases the systematic error on the equivalent width of the HVC O VI components from 23 to 47 mÅ (for the −295 km s^{-1} component) and from 25 to 61 mÅ (for the −180 km s^{-1} component).

This sightline passes only about 1° from the 2×10^{18} cm^{-2} contour of HVC WW466 (the HVC near M33; Wright 1974), which has velocities of about −365 km s^{-1}. The high-velocity O VI component may be associated with that cloud, although similar high-velocity O VI is seen in every sightline in this part of the sky, whether or not the sightline passes close to a H I HVC. It is possible that there is Lyβ absorption corresponding to H I outside the 21-cm contour. However, the higher Lyman lines cannot be checked since there is no SiC data. The optical depth of any C II λ1036.337 associated with WW466 is <0.2.

M 33 lies 7$^\circ\!\!.$4 (90 kpc) away; see Sect. 5.4 for further discussion.

Mrk 357

The LiF1A and LiF2B spectra differ somewhat, especially in the depth of the HVC feature.

This is one of two sightlines where intermediate-velocity H_2 contaminates the O VI line (PG 1351+640 being the other). After removing the H_2 λ1031.191 absorption, we interpret the HVC absorption as showing two components, centered at -280 and -185 km s^{-1}. However, because of the H_2 contamination the systematic uncertainty on both components is rather large.

The sightline passes only 3° from the outer contour of HVC WW466 (the HVC near M33, Wright 1974), which has velocities similar to the O VI-HVC component. There is not enough signal in the SiC channels to search for associated Lyman lines. The optical depth of C II λ1036.337 is <0.2.

M 33 lies 7$^\circ\!\!.$9 (96 kpc) away; see Sect. 5.4 for further discussion.

Mrk 421

The high-positive velocity wing on the O VI profile is not clearly separated from the Galactic component. In several nearby directions such a wing is also seen, but with a clearer separation: at 95 km s^{-1} toward HS 1102+3441 (4° away), at 100 km s^{-1} toward PG 0947+396 (14° away), and at 115 km s^{-1} toward PG 1116+215 (18° away). Toward Mrk 421 the wing extends rather far and the separation was placed at 100 km s^{-1}. The wing is rather weak, however: 37±11±29 mÅ.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range -130 to 100 km s^{-1} the ratio N(1037)/N(1031) is 1.60±0.18, making this one of two sightlines with substantial saturation (the other is Mrk 876).

The galaxy group GH75 (v=1025 km s^{-1}) and the Leo Spur (v=620±160 km s^{-1}) are sampled by this sightline, but no intergalactic absorption is apparent.

Mrk 478

The O VI absorption in this direction is clearly offset from 0 km s^{-1} and is centered at -20 km s^{-1}.

The sightline passes through the Canes Venatici Spur (v=1140±250 km s^{-1}). A *STIS* spectrum of Mrk 478 shows Lyα absorption at v=1560 km s^{-1}. A corresponding weak Lyβ feature is seen at 1031.119 Å (v=-235 km s^{-1} on the O VI velocity scale) in the *FUSE* spectrum.

The 79±17 mÅ feature at 1033.238 Å (380 km s^{-1} on the O VI velocity scale) may be O VI. It cannot be Lyβ at 2170 km s^{-1}, as there is no corresponding Lyα line in the *STIS* spectrum of Mrk 478. There is a 32±20 mÅ feature in the 1037 line that may correspond to it. There is also a feature at 1027.179 mÅ that may be Lyβ at 425 km s^{-1}. More exposure time is needed to positively identify the feature.

Mrk 487

There is a component in the C II line at -140 km s^{-1}, although there is no H I detected at this velocity. However, both to the north and to the south, HVC complex C is detected at similar velocities in 21-cm emission.

Mrk 501

This is one of 9 sightlines where O VI absorption is detected at velocities where complex C is seen in H I. However, in this direction, the IVC complex K is also present. It is not clear at which velocity to separate the Galactic and HVC component. A choice was made to cut at a velocity of -100 km s^{-1}, which is also about where the complex C and K components can be separated in H I.

The sightline also passes through the Draco Galaxy Grouping (v=1120±390 km s^{-1}), as well as through grouping #70, whose galaxies have v=2320±400 km s^{-1}. No inter-group Lyβ is seen.

Note the feature at 1035.596 Å (60±15 mÅ) It cannot be Lyβ since there is no corresponding Lyα line in the *GHRS* spectrum. It is most likely C II at a velocity of -215 km s^{-1}. The nearest H I with similar velocities are parts of complex C that lie about 5° away (N(H I)$\sim$2$\times$10^{18} cm^{-2}). If it is C II in complex C, the corresponding H I column density would also be about 2$\times$10^{18} cm^{-2}.

Mrk 506

This is one of 9 sightlines with O VI associated with HVC complex C. The velocity extents of the O VI and the H I are similar. The HVC and Galactic components were separated at -100 km s^{-1}, because the O VI components seem to be split there.

The negative-velocity edge of the -145 km s^{-1} O VI component is contaminated by the H_2 J=3 line, increasing the systematic error from 34 to 39 mÅ.

There is a feature at 1032.549 Å (180 km s^{-1} on the O VI velocity scale), which appears to be present in both the LiF1A and LiF2B channels, and measures as a 2.0σ feature. It cannot be H_2 J=4. It is at the right velocity to be intrinsic Si II λ989.873, but since no intrinsic Lyβ is seen this is unlikely. Possibly, the feature is weak Lyβ at 1995 km s^{-1}, although there are no known galaxy groups in this direction. It is unlikely that it is high-positive velocity O VI because it is narrow (b=18 km s^{-1}). This feature may not be real.

Mrk 509

This is among the 10 sightlines with the highest S/N ratio (26 per resolution element). The flux seems to vary over time, being 12$\times$10^{-14} erg cm^{-2} s^{-1} Å^{-1} on 1999 November 2, but 5$\times$10^{-14} erg cm^{-2} s^{-1} Å^{-1} on 2000 September 5.

The high-negative velocity HVC component is split in two parts by Galactic H_2, but after removing this, it becomes a fairly clear single component lying between -390 and -180 km s^{-1} with a secondary component between -180 and -100 km s^{-1}. However, the systematic error is increased from 11 to 31 mÅ. Similarly, on the positive-velocity side, the wing becomes clearer after removal of the H_2 J=4 line. The component at v=150 km s^{-1} is a 7.0σ detection.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range -40 to 100 km s^{-1} the ratio N(1037)/N(1031) is 0.99±0.05.

C II absorption is seen at a velocity of -295 km s^{-1}, with W=53±10 mÅ, or N(C II)$\sim$6$\times$10^{13} cm^{-2}. Assuming carbon is not depleted on dust, this corresponds to N(H I)=0.2$\times$10^{17}/Z cm^{-2}, with Z the metallicity in solar units. The Green Bank spectrum sets a 3σ upper limit of $\sim$2$\times$10^{18} cm^{-2} on N(H I). A similar component is seen in the C II λ1334.532 line (Sembach et al. 1999).

Mrk 618

This sightline shows unusually narrow O VI absorption, similar to that seen in the two objects nearest to it (Mrk 1095 and HE 0450−2958).

Mrk 734

This is one of two sightlines where very little negative-velocity O VI absorption can be discerned. However, the O VI λ1037.617 line seems weaker than expected from the O VI λ1031.926 line. Some of this may be because of low S/N, as there is a difference between the LiF1A and LiF2B channels – the 1037 line is more visible in LiF2B. The noise is sufficiently high that the differences are (barely) acceptable within the errors: W(1031)=282±30±30 mÅ, while W(1037)=65±50±14 mÅ, where a value of 120–170 mÅ is expected. There also seems to be strong positive-velocity O VI, but the corresponding 1037 line is hidden in the H_2 J=1 line.

The H_2 J=4 line contaminates the edges of both the thick disk and the HVC O VI absorption, but it can be determined well enough that the systematic errors increase only sightly.

The sightline passes through the Leo Spur (v=620±160 km s^{-1}), the Leo Galaxy Grouping (v=1390±390 km s^{-1}) as well as GH78 (v=1200 km s^{-1}). Three galaxies in the Leo Spur (v=620±160 km s^{-1}) have an impact parameter of ∼200 kpc (NGC 3627, v=623 km s^{-1}, NGC 3623 (v=693 km s^{-1}) and NGC 3593 (v=510 km s^{-1}). The absorptions at 1027.460 Å and 1028.353 Å are Lyβ at v=510 km s^{-1} and v=770 km s^{-1}; the corresponding Lyγ and Lyδ lines are weak but probably present. The feature at 1034.506 Å is most likely O VI λ1031.926 at 750 km s^{-1}, associated with one of the Lyβ absorbers. No absorption is seen in the more distant groups.

Mrk 771

There may be a slight calibration problem for this spectrum, as the flux does not go down to zero in the C II λ1036.337 line. Also, the LiF1A and LiF2B spectra differ substantially – the O VI absorption is much stronger in the LiF1A channel. However, because of the low S/N ratio this difference still lies within the noise. The most serious problem, however, is that the O VI λ1031.926 line is probably contaminated by Lyβ. In the *STIS* spectrum of this object three Lyα absorbers can be seen, at velocities of 1170, 1875 and 2545 km s^{-1}, with equivalent widhts of ∼250 mÅ. Depending on the b-value the predicted strength of the corresponding Lyβ lines is ∼100 mÅ. The Lyβ line at 1875 km s^{-1} is expected at 1032.138 Å, or 60 km s^{-1} on the O VI λ1031.926 velocity scale. It is thus likely that O VI λ1031.926 is contaminated by Lyβ. That this is the case is also suggested by the fact that the O VI λ1037.617 line is a factor two to three weaker than expected. Fortunately, this line is uncontaminated, and the continuum can be determined well enough that we decided to use O VI λ1037.617 to measure N(O VI). This is the only sightline for which this was possible.

Mrk 817

This is among the 10 sightlines with the highest S/N ratio (29 per resolution element). It is also one of 9 sightlines in which complex C is seen in O VI absorption. The separation between the HVC and Galactic components is not clear, however. A cut was made at a velocity of −90 km s^{-1}, which is at the minimum of the H I emission, and is where the O VI profile shows a slight rise. This is probably real, as the S/N ratio is high.

The flux of Mrk 817 changes from one observation to the next. It was 9×10^{-14} erg cm^{-2} s^{-1} Å^{-1} on 2002 February 17, 6×10^{-14} erg cm^{-2} s^{-1} Å^{-1} on 2000 December 23, and 13×10^{-14} erg cm^{-2} s^{-1} Å^{-1} on 2001 February 18. These fluctuations are probably intrinsic.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range -90 to 60 km s^{-1} the ratio N(1037)/N(1031) is 1.28±0.07, showing that some saturation is present.

The extended ledge at positive velocities is intergalactic Lyβ absorption associated with the Canes Venatici Galaxy Grouping (v=2360±330 km s^{-1}) (more specifically, with GH144, v=2320 km s^{-1}). The sightline passes just 0°.6 (330 kpc impact parameter) from UGC 9391 v=2097 km s^{-1}). Penton et al. (2000) report Lyα absorption in a *GHRS* spectrum, with velocities of 1933 and 2097 km s^{-1}, equivalent widths of 29±13 and 135±15 mÅ, and b-values of 34±13 and 40±4 km s^{-1}. The corresponding Lyβ lines are then expected at 1032.336 and 1031.897 Å, or 119 and 282 km s^{-1} on the O VI velocity scale, with equivalent widths of 4±3 and 21±3 mÅ. The feature between 145 and 320 km s^{-1} has an equivalent width of 66±10 mÅ, and clearly is Lyβ. The weaker intergalactic absorption would be too weak too discern, implying that the feature in the wing of the O VI line between 60 and 145 km s^{-1} must be high positive-velocity O VI.

Mrk 829

The Galactic O VI absorption sits in the wing of broad intrinsic Lyβ absorption. This galaxy is part of the Canes Venatici Spur (v=1140±250 km s^{-1}).

Mrk 876

This is one of 9 sightlines toward which O VI associated with HVC complex C is seen. Both the H I and the O VI have an extended wing out to -200 km s^{-1}. The cut between the HVC and the Galactic component was placed at -100 km s^{-1}, as there are no objective criteria to use.

The H_2 J=3 line contaminates the negative-velocity edge of the HVC absorption, but it has only a minor influence on the measurement of the equivalent width. The weak positive-velocity feature is more strongly contaminated by the H_2 J=4 line, and it may not be real.

At first sight, the O VI λ1037.617 line appears uncontaminated, while there appears to be some saturation in the O VI lines. However, it turns out that the *STIS* spectrum shows a Lyα line at a velocity of 3457 km s^{-1}. This has an equivalent width of 245 mÅ, and a fitted FWHM of 63 km s^{-1}. With those parameters the corresponding Lyβ should be a 46 mÅ feature lying between -30 and 30 km s^{-1} on the O VI λ1037.617 velocity scale. In this velocity range the equivalent width of O VI λ1031.926 is 113 mÅ, while that of O VI λ1037.617 is 95 mÅ. The latter could very well be the sum of 46 mÅ due to Lyβ and 49 mÅ due to O VI. We therefore conclude that there is no evidence for O VI saturation, but that instead the O VI λ1037.617 line is contaminated by intergalactic Lyβ.

The sightline passes through the Draco Galaxy Grouping (v=1120±390 km s^{-1}), but no intergalactic Lyβ is seen at its velocities. The Ursa Minor dwarf spheroidal (v=17 km s^{-1}, radius 1.4 kpc) lies 6°.6 away (12 kpc impact parameter), but any associated O VI would be hidden in the main Galactic absorption.

The feature at 1035.175 Å cannot be intergalactic Lyβ at 2725 km s^{-1}, as there is no Lyα absorption at that velocity in the *STIS* spectrum of Mrk 876. It is also unlikely to be interstellar C II at -330 km s^{-1}, as there is no known H I with similar velocities within tens of degrees. It is most likely intergalactic O VI at 945 $\mathrm{km\,s^{-1}}$, with a small amount of H_2 J=4 included. Other H_2 J=4 lines of similar strength are much weaker, though not absent. There is a possible 2σ (20 mÅ) counterpart in the night-only LiF1A channel at 1040.744 Å, which corresponds to 905 $\mathrm{km\,s^{-1}}$ on the O VI λ1037.617 velocity scale. However, even in the night data this feature may be affected by geocoronal OI* emission. There is Lyα absorption at v=935 $\mathrm{km\,s^{-1}}$ in the *STIS* spectrum of Mrk 876. The corresponding Lyβ is heavily contaminated by the 1028.986 Å H_2 J=3 line, but the feature near this wavelength has a much broader base then expected if it were just H_2, especially when compared to the other J=3 lines.

The large (37 kpc at 25 mag surface brightness), relatively isolated SB galaxy NGC 6140 (v=1147 $\mathrm{km\,s^{-1}}$; part of the Draco Galaxy Grouping (v=1120±390 $\mathrm{km\,s^{-1}}$)) has an impact parameter of just 260 kpc. It is likely that the 940 $\mathrm{km\,s^{-1}}$ Lyα, Lyβ and O VI absorptions are associated with this galaxy.

Mrk 926

This spectrum has an S/N of 3 per resolution element, and is the noisiest included in the final sample. It is still clear that the Galactic O VI absorption is weak. O VI absorption can be seen between −130 and −65 $\mathrm{km\,s^{-1}}$, while between −65 and 100 $\mathrm{km\,s^{-1}}$ only a 3σ upper limit of 215 mÅ can be set (log N(O VI)<14.23). High-velocity O VI absorption extends from −395 to −65 $\mathrm{km\,s^{-1}}$ and can be split into two components. This absorption is rather clear and similar to that seen in many other nearby sightlines.

The 3σ feature at 1032.757 Å (240 $\mathrm{km\,s^{-1}}$ on the O VI velocity scale) is more difficult to identify. It might be O VI, but the 1037 line is too noisy to confirm this. It might be Lyβ, but no verifying Lyα spectrum exists (the sightline passes through the Pisces Austrinis Spur (v=2590±260 $\mathrm{km\,s^{-1}}$)). However, it is most likely a noise feature in the LiF2B channel, as it is less clear in LiF1A.

The feature near 1034.748 Å (820 $\mathrm{km\,s^{-1}}$ on the O VI velocity scale) is unidentified. It is no Lyβ as there is no Lyα absorption at corresponding velocities in the *STIS* spectrum.

C II absorption is seen at a velocity of −240 $\mathrm{km\,s^{-1}}$, with W=120±45 mÅ, or N(C II)$\sim 3\times10^{14}$ $\mathrm{cm^{-2}}$. Assuming carbon is not depleted on dust, this corresponds to N(H I)$>0.9\times10^{17}$/Z $\mathrm{cm^{-2}}$, with Z the metallicity in solar units. The Green Bank spectrum sets a 3σ upper limit of $\sim 6\times10^{17}$ $\mathrm{cm^{-2}}$ on N(H I).

Mrk 1095 (Akn 120)

This sightline shows narrow Galactic O VI, similar to that seen in the neighboring directions toward Mrk 618 and HE 0450−2958.

The feature at 1030.578 Å (−390 $\mathrm{km\,s^{-1}}$ on the O VI velocity scale) is obvious and strong in the LiF2B channels of both observations, but may be absent in the LiF1A channels. The measured b-value is very low (14 $\mathrm{km\,s^{-1}}$). This casts doubt on its reality, even though in the combined spectrum it nominally is a 3.4σ detection. If this feature were intergalactic Lyβ at v=1420 $\mathrm{km\,s^{-1}}$, the corresponding Lyα line would have an equivalent width of 140 mÅ. Unfortunately, it is not possible to check this, as this line would be at λ=1221.420 Å, whereas the *GHRS* spectrum of Mrk 1095 only extends to 1222.4 Å (see Penton et al. 2000, who use the name Akn 120). The *FOS* spectrum may show a feature at the right wavelength, but is rather noisy. However, the absence of a known galaxy group with similar velocities argues against an interpretation as Lyβ. We list it as "unidentified".

Mrk 1383

In principle the O VI line could be contaminated by Lyδ absorption intrinsic to Mrk 1383, which is expected at v(O VI)=-17 km s^{-1}. However, no other Lyman lines are seen at the redshift of Mrk 1383.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range -100 to 100 km s^{-1} the ratio N(1037)/N(1031) is 1.23$\pm$0.08, showing that some saturation is present.

The feature at 1032.356 Å (125 km s^{-1} on the O VI velocity scale) is clearly significant and unusual. It is seen in both observations. The sightline passes through the Virgo-Libra Galaxy Grouping (v=1820$\pm$490 km s^{-1}), with several galaxies lying 2–3° away (1–1.5 Mpc impact parameter). Even though this sightline also passes through GH145 ($v\sim$1880 km s^{-1}), this feature cannot be Lyβ at 1940 km s^{-1}, as there is no corresponding Lyα feature at 1223.529 Å in the *STIS* spectrum of this target. On the other hand, there is a hint of a counterpart in the O VI λ1037.617 line, so it is probably high-velocity O VI.

Mrk 1502

The strength of the high-velocity component differs somewhat in the LiF1A channels of the two observations. The LiF2B channel of the first observation contains no flux and was not used.

The negative-velocity edge of the HVC O VI component is contaminated by H_2 J=3, which increases the systematic error from 29 to 37 mÅ.

Intrinsic Lyγ would be at v(O VI)=21 km s^{-1}, but no other intrinsic Lyman lines are seen.

Mrk 1513

The positive-velocity edge of the HVC O VI component is contaminated by the H_2 J=3 line, which results in increasing the systematic error from 28 to 33 mÅ.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range -75 to 80 km s^{-1} the ratio N(1037)/N(1031) is 1.02$\pm$0.22.

The feature at 1033.346 Å (415 km s^{-1} on the O VI velocity scale) is C III λ977.020 at z=0.05765 (v=17280 km s^{-1}), an associated system in which Lyα to Lyζ and O VI are also seen. The velocity of this system relative to Mrk 1513 is -1600 km s^{-1}. As this is a relatively small velocity difference with respect to an AGN, we cannot rule out that this absorption system is associated with Mrk 1513, rather than an intergalactic cloud.

The sightline passes through the edge of the Pegasus Galaxy Grouping (v=2170$\pm$480 km s^{-1}), but no intergalactic absorption is visible within 1200 km s^{-1} of O VI λ1031.926.

MS 0700.7+6338

The sightline passes $\sim$1 Mpc from the edge of the Lynx Galaxy Grouping (v=1850$\pm$280 km s^{-1}), but no obvious associated Lyβ can be seen.

NGC 588

The LiF1A and LiF2B spectra appear to show some differences. However, the differences lie within the noise.

This object is an H II region in M 33. The spectrum is therefore an amalgam of the radiation from many O stars. However, the region near O VI λ1031.926 looks fairly clean – it is probably dominated by the hottest and brightest stars. Absorption at Milky Way velocities is very weak – the 3σ upper limit is 110 mÅ (log N(O VI)<14.07). This is consistent with the weak Milky Way lines seen in the nearby sightlines to Mrk 352 (7°.1 away), Mrk 357 (7°.8 away) and PG 0052+251 (9°.8 away). The high-negative velocity O VI components are also seen toward those sightlines. The LSR velocity of the H I in M 33 at the position of NGC 588 is -220 km s^{-1} (Deul & van der Hulst 1987), but the O I λ1039.230, Ar I λ1048.220 and Si II λ1020.699 absorption lines are centered at -180 km s^{-1}, while the C II λ1036.337 absorption extends to -230 km s^{-1}.

A-priori one might favor an interpretation in which the O VI components at -370 (W=122$\pm$27$\pm$18 mÅ) and especially the one at -210 km s^{-1} (W=301$\pm$31$\pm$25 mÅ) are associated with M 33. However, similar components are seen toward Mrk 352 (at -295 and -180 km s^{-1}, W=103 and 123 mÅ), toward Mrk 357 (at -280 and -185 km s^{-1}, W=131 and 80 mÅ) and toward PG 0052+251 (at -335 and -195 km s^{-1}, W=153 and 77 mÅ), as well as toward all other sightlines in this part of the sky. Comparing these, it is clear that the -370 km s^{-1} component toward NGC 588 has an equivalent width that is similar to that of the other very-high negative velocity components. The -210 km s^{-1} component, however, is much stronger and this component is probably dominated by absorption associated with M 33. It is not possible, however, to disentangle the relative contributions from M 33 and the more extended high-negative velocity O VI.

NGC 592

This is an H II region in M 33, but unlike NGC 588, the combined O-star spectrum does not provide a simple continuum, and this sightline is not included in the final sample.

NGC 595

The LiF1A and LiF2B spectra appear to show some differences. However, they lie within the noise.

Like NGC 588, this object is an H II region in M 33. The spectrum is therefore an amalgam of that of many O stars. The region near O VI λ1031.926 looks fairly clean. Only a 3σ upper limit of 126 mÅ (log N(O VI)<14.00) can be set on the Milky Way absorption. This is consistent with the weak Milky Way lines seen in the nearby sightlines to Mrk 352 (7°.1 away), Mrk 357 (7°.8 away) and PG 0052+251 (9°.8 away). Two strong high-negative velocity O VI components are also detected. See the notes for NGC 588 for further comments.

NGC 604

This is the brightest of the four H II regions in M 33 that were observed by *FUSE*. However, the continuum placement near 1032 Å is unclear, as there is a sharp upturn at slightly longer wavelengths. This target was therefore not included in the final sample.

NGC 985

The feature at 1031.215 Å (-205 km s^{-1} on the O VI velocity scale) is broader than expected if it is solely H_2, but after removal of the H_2 line it is too weak to measure, so we decided that it is probably not real.

The sightline passes through the middle of the Cetus-Aries Galaxy Grouping (v=1810±510 km s^{-1}), and 35 arcmin (190 kpc impact parameter) from NGC 988, which has v=1504 km s^{-1}. However, there is no inter-group Lyβ, nor are there Lyα features near 1222.18 Å in the *STIS* spectrum of NGC 985.

NGC 1068

This object is bright, and in the O VI λ1031.926 region the flux is even higher because of the wing of strong O VI emission (peak flux 8.5×10^{-13} erg cm^{-2} s^{-1} Å^{-1}) intrinsic to NGC 1068. The continuum still seems fairly easy to determine in the region near 1032 Å.

There is a feature centered at 1033.463 Å (445 km s^{-1} on the O VI velocity scale). This is probably O VI associated with NGC 1068, although its counterpart is confused with the low-velocity Galactic O I λ1039.230 absorption. NGC 1068 is part of the Cetus-Aries Galaxy Grouping (v=1810±510 km s^{-1}), but none of the galaxies near NGC 1068 that are part of this group has a velocity as low as 500 km s^{-1}, so no intergalactic Lyβ is expected.

NGC 1399

The Lyβ absorption associated with NGC 1399 is very strong, and reduces the S/N ratio in the continuum near the O VI λ1031.926 line to about 3.5 per resolution element. However, it can clearly be established that the Galactic O VI absorption is weak. The S/N ratio near the O VI λ1037.617 line is $\sim$8, and a good measurement is possible. The two measurements are in good agreement, giving W(O VI λ1031.926)=124±39±21 mÅ, and W(O VI λ1037.617)=70±23±36 mÅ. Both are $\sim3\sigma$ detections, but the column density ratio is $\sim$1. In Table 2 the O VI λ1031.926 measurement is listed, but in the channels maps of Fig. 10 the O VI λ1037.617 column densities are used, since it has a better S/N ratio.

This galaxy is part of the Fornax-Eridanus Galaxy Grouping (v=1580±490 km s^{-1}), and several other galaxies have an impact parameter of <150 kpc. However, they have similar velocities and it is not clear whether they are in front or behind NGC 1399.

NGC 1705

This is among the 10 sightlines with the highest S/N ratio (23 per resolution element). Heckman et al. (2001) present a detailed analysis of this sightline. The continuum placement is somewhat difficult. We decided that the flux at 1034.5 Å represents the continuum level. The implication of this choice is that there is absorption at all velocities between the Galactic and HVC components at 0 and +325 km s^{-1}. On the other hand, this velocity range may show absorption associated with NGC 1705. Unfortunately, the continuum is too complicated to check this using the O VI λ1037.617 line. Heckman et al. (2001) chose the continuum to be much lower, and do not list the intermediate (180 km s^{-1}) component. This would imply a strong wiggle and a sharp upturn at 1034 Å. This could be justified by arguing that the O VI in NGC 1705 has a P-Cygni profile. It would yield an equivalent width of 180±9 mÅ between v=−70 and 105 km s^{-1} for the Milky Way (rather than 239±15 between −120 and 120 km s^{-1}) and of 120±8±9 Å between v=265 and 400 km s^{-1} for the HVC component (rather than 200±9 km s^{-1}). Half the difference between these values and the values derived from the higher-placed continuum is included in the systematic error.

The HVC absorption between 245 and 435 km s^{-1} is associated with HVC WW487 (Wakker & van Woerden 1991), which was also detected in several other absorption lines by Sahu & Blades (1997).

The feature at 1033.816 Å (550 km s^{-1} on the O VI velocity scale) is O VI associated with NGC 1705.

NGC 3310

In this sightline the H_2 lines near O VI look very broad. Weaker J=2 and J=3 lines show that there is H_2 absorption associated with both the low- and the intermediate-velocity gas in the sightline. The strongest H_2 absorption is associated with the IV-Arch, and this is used to align the spectrum. Just using the Si II λ1020.699 and Ar I λ1048.220 lines would lead to an incorrect alignment.

This is one of 3 sightlines where the thick disk O VI extends to more negative velocities than -120 km s^{-1} (to -135 km s^{-1}), but in which there is no obvious separate high-velocity component. This sightline passes through the Ursa Major window and HVCs complexes A and C lie just a few degrees away. The negative-velocity wing may be associated with O VI around the edges of these HVC complexes.

NGC 3504

Although the S/N ratio in this spectrum is low (3.3 per resolution element), the Galactic O VI line clearly is very weak. The 3σ limit for the -70 to 70 km s^{-1} velocity range is 190 mÅ (log N(O VI)<14.19). Just one degree away lies Mrk 36, toward which W(O VI)= 232±57 mÅ.

The intrinsic Lyβ line in NGC 3504 is clearly visible, and centered at about 1370 km s^{-1}. The galaxy's spectrum further shows a depression in the region between 1030 and 1040 Å. This makes the flux near the Galactic O VI absorption rather low, and the resulting upper limit rather high.

NGC 3690

Although this galaxy is bright, and Galactic O VI absorption is clearly present, it cannot be measured since the continuum placement is too uncertain, partly because intrinsic, redshifted Si II λ1020.699 overlaps the negative-velocity wing of the O VI.

NGC 3783

Although this is a bright object with a high S/N spectrum, the contamination by both H_2 and intrinsic lines is too severe to allow a reliable measurement of the Galactic O VI line, even though it is clearly present.

NGC 3991

The spectra in the LiF1A and LiF2B channels look somewhat different, but especially the LiF2B channel is rather noisy. The combined spectrum was still used.

The short wavelength wing of the Lyβ absorption associated with NGC 3991 extends to near the O VI λ1031.926 line, but only marginally distorts the continuum there. A major problem with this sightline is that the Si II λ1020.699 line associated with NGC 3991 lies adjacent to the negative-velocity edge of the O VI λ1031.926 absorption. Fitting other intrinsic lines (C II λ1036.337, O I

λ1039.230, Ar I λ1048.220, Si II λ989.873) shows that the feature centered at -108 km s^{-1} is Si II λ1020.699 in NGC 3991. This feature was fitted and removed before measuring the Galactic N(O VI).

NGC 4151

The Galactic O VI line sits in a relatively clean part of the spectrum, which shows strong emission lines associated with NGC 4151. The components seen in O VI can also be identified in the C IV profile, which was analyzed by Brandt et al. (2001).

There is a second *FUSE* spectrum of this object (P2110201), which we did not include in our analysis, as it has a shorter integration time. However, this observation shows that the feature at 1032.520 Å (175 km s^{-1} on the O VI velocity scale) is time-variable and thus associated with NGC 4151.

NGC 4214

This object is bright and the observation is relatively long, resulting in a spectrum with high S/N ratio (12 per resolution element). Strong Galactic O VI absorption can be seen, as well as strong O VI and Lyβ associated with NGC 4214. However, the continuum placement in the 1030–1034 Å wavelength region is too uncertain. Placing it low would yield W(O VI)=165$\pm$25 mÅ, whereas placing it high gives W(O VI)=265$\pm$20 mÅ. Both of these continuum placements can be defended. Because of this large uncertainty NGC 4214 was excluded from the final sample.

NGC 4649

The Galactic O VI line lies in the wing of the strong Lyβ line associated with the galaxy itself, which is a galaxy in the Virgo cluster. This substantially reduces the S/N ratio, but the Galactic O VI line is still clearly visible and can easily be measured.

NGC 4670 (Haro 9)

This passes within 1°.5 of the North Galactic Pole: b=88°.6.

Intrinsic Lyβ absorption can clearly be seen, centered at 1040 km s^{-1}.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range -80 to 80 km s^{-1} the ratio N(1037)/N(1031) is 0.88$\pm$0.17.

The feature at 1033.155 Å is O VI absorption at v=355 km s^{-1}. There is clearly a counterpart in the other line of the doublet. The velocity of this O VI doublet relative to NGC 4670 is -720 km s^{-1}. Since NGC 4670 is a dwarf galaxy (albeit one with vigorous star formation), it seems unlikely that this O VI absorption is associated with that galaxy. In no other direction in this part of the sky is O VI absorption seen at such high positive velocities (see Fig. 10l). There is also absorption at this velocity in the Lyβ, Lyγ and Lyϵ lines (Lyδ is blended with Galactic O I).

NGC 5236 (M 83)

This galaxy is a nearby, large starburst (velocity 516 km s^{-1}, diameter 16.1 kpc or 1.2 arcmin at its distance of 4.7 Mpc). The *FUSE* aperture covers only part of the galaxy. The flux is probably due to a mixture of many O stars. Very strong O VI absorption is seen between -200 and 740 km s^{-1}, but the Galactic contribution is unclear. This sightline was therefore excluded from the final sample.

NGC 5253 (Haro 10)

This small (3.4 kpc diameter), nearby (3.2 Mpc) starburst was observed using the MDRS aperture. A strong, wide Lyβ line can be seen, which is so wide that the continuum near O VI λ1031.926 becomes uncertain. O VI absorption near 400 km s^{-1} that is associated with NGC 5253 is also seen, as is absorption at all velocities between 100 and 450 km s^{-1}. Thus, not only is the continuum difficult to place, it is further unclear which absorption is Galactic and which is not. NGC 5253 was therefore excluded from the final sample.

NGC 5461

This object is an H II region in M 101. Broad O VI absorption can be discerned, which is a mixture of Galactic O VI and O VI in NGC 5461. In addition, the S/N ratio is low and the placement of the continuum is difficult. This sightline was therefore excluded from the final sample.

NGC 5548

The O VI absorption looks narrower in the LiF2B channel than in the LiF1A channel, but both channels were combined to create the final spectrum.

NGC 7469

The strong high-negative velocity HVC component is split in two by the Galactic H_2 J=3 absorption, making the equivalent width measurement difficult. However, some of the absorption near -210 km s^{-1} is O VI, rather than H_2. After removal of the H_2 line, the high-velocity component can be split in two components. This direction lies within the tip of the H I Magellanic Stream, and there is H I at -333 km s^{-1}. Thus, some of the O VI HVC component at -305 km s^{-1} may be associated with the Stream.

The systematic error on the equivalent width and column density of the high-negative velocity components reflects the uncertainty in the H_2 parameters. This increases the systematic errors from 9 to 21 mÅ and from 17 to 40 mÅ for the -305 and -185 km s^{-1} O VI components, respectively.

Based on the strength of the H_2 J=0 and J=1 lines (they have damping wings, and N(H_2)>10^{19} cm^{-2}), the HD line at 1031.912 Å may be present. At the wavelengths of the HD 3–0 R(0) through 8–0 R(0) lines at 1066.271, 1054.433, 1042.847, 1031.912, 1021.456 and 1011.457 Å (Dabrowski & Herzberg 1976) features with equivalent widths of 21±8, 12±6, 29±11, 19±7, 15±7 and 15±7 mÅ respectively, can be measured. It is therefore likely that the sharp feature centered at 1031.912 Å is HD. This feature was removed before calculating for the Galactic O VI parameters.

The sightline passes through the Pegasus Spur (v=1110±260 km s^{-1}) and the edge of the Pegasus Galaxy Grouping (v=2170±480 km s^{-1}). The absorption between -375 and -120 km s^{-1} cannot be intergalactic Lyβ since the corresponding Lyα absorption is not seen in the *FOS* spectrum of NGC 7469. A strong Lyα line is found at v=3070 km s^{-1}. The corresponding Lyβ absorption mostly overlaps the low-velocity C II λ1036.337 line, and it causes the sloped negative-velocity wing on that line.

C II absorption is seen at a velocity of -335 km s^{-1}, with W=185±10 mÅ. An H I component with N(H I)=3.3×10^{18} cm^{-2} is seen in the Effelsberg spectrum with a FWHM of 27 km s^{-1}. This is compatible with the C II absorption for gas with Magellanic abundances.

NGC 7496

Strong intrinsic Lyβ absorption centered at v=1370 km s^{-1} in NGC 7496 hides the Galactic O VI line.

NGC 7673

Absorption in NGC 7673 is seen in the Lyβ, Lyγ, Lyδ, Lyϵ and C II λ1036.337 lines, centered near the nominal velocity of 3408 km s^{-1}. This places the intrinsic Si II λ1020.699 line at 1032.302 Å, or 112 km s^{-1} on the O VI velocity scale. The Lyβ damping wings indicate that N(H I)$\sim$1.4$\times$10^{21} cm^{-2}. Most of the low-ion lines appear to be very broad; they seem to be several hundred km s^{-1} wide (e.g., the C II λ1036.337 line seems to range from 3000 to 3600 km s^{-1}) Si II λ989.873 is also present, and strong. The Si II λ1020.699 line will have an optical depth that is 10 times lower, on the order of 0.1–0.5. The upshot of the presence of the strong, wide intrinsic low-ion lines is that the continuum near the Galactic O VI λ1031.926 line is very unreliable and thus we do not include this sightline in the final sample.

NGC 7714

This direction lies within the tip of the Magellanic Stream and there is H I at v=$-$316 km s^{-1}. The high-velocity O VI component lies at slightly less negative velocities. It may or may not be associated with the Magellanic Stream.

Absorption in NGC 7714 is seen in the Lyβ, C II, Si II λ1020.699, Fe II λ1144.938 and Fe II λ1063.176 lines, centered at a velocity of 2725 km s^{-1}. This places the intrinsic Si II λ1020.699 line at 1029.975 Å ($-$565 km s^{-1} on the O VI velocity scale). This line therefore does not contaminate the Galactic O VI.

PG 0052+251

The Galactic O VI component is very weak in this direction. The 3σ upper limit is 115 mÅ (log N(O VI)<13.97). This sightline crosses a HVC at $-$121 km s^{-1} (WW478), but no O VI absorption is seen at those velocities. The sightline also lies only about 2° from cloud WW466 (the HVC near M33, Wright 1974), which has a velocity of $-$365 km s^{-1}. High-velocity O VI absorption at similar velocities is clearly seen. This 4.6σ component may be associated with that cloud, or the O VI and/or H I may be Local Group gas. A secondary 3.5σ component is also seen at $-$195 km s^{-1}.

C II absorption is seen at a velocity of $-$285 km s^{-1}, with W=78$\pm$29 mÅ, or N(C II)$\sim$1$\times$10^{14} cm^{-2}. Assuming carbon is not depleted on dust, this corresponds to N(H I)=0.3$\times$10^{17}/Z cm^{-2}, with Z the metallicity in solar units. The Green Bank spectrum sets a 3σ upper limit of $\sim$3$\times$10^{18} cm^{-2} on N(H I).

PG 0804+761

There are two observations for this object. The flux on 1999 October 5 was 9$\times$10^{-14} erg cm^{-2} s^{-1} Å^{-1}, while on 2000 January 4 it was 14$\times$10^{-14} erg cm^{-2} s^{-1} Å^{-1}. This change may be due to a problem with early *FUSE* spectra, but it also may be due to an intrinsic change in the flux.

The redshift of PG 0804+761 is given as 0.100 by *NED*, based on the original data from Green et al. (1986). However, as Richter et al. (2001a) discuss, the actual redshift is probably 0.102.

The feature at 1033.867 Å (564 km s^{-1} on the O VI velocity scale) is intrinsic Lyϵ. Lyβ

and Lyγ are detected (Richter et al. 2001a), with equivalent widths that are compatible with this interpretation.

This sightline passes about 0$^\circ\!\!.$4 (170 kpc impact parameter) from UGC 4238 (v=1714 km s^{-1}), which is part of the Ursa Major Galaxy Grouping (v=1360±540 km s^{-1}). No associated Lyβ absorption is visible.

PG 0832+251

In spite of low S/N (3.5 per resolution element) this sightline gives a fairly clean detection of Galactic O VI.

The sightline passes through the Cancer-Leo Galaxy Grouping (v=2600±290 km s^{-1}). The feature at 1033.106 Å (345 km s^{-1} on the O VI velocity scale) is probably Lyβ at 2160 km s^{-1}. Observations of Lyα are required to confirm this interpretation.

PG 0832+675

This is one of two distant halo stars in the sample (d=8.1 kpc, z=4.7 kpc; Ryans et al. 1997, spectral analysis by Hambly et al. 1996). The star is classified as a post-AGB star, with T=23,000 K. It is one of three sightlines toward HVC complex A. A relatively large number of unidentified, but probably stellar, features can be seen. Since there is no C II λ1036.337, Si II λ1020.699 or O I λ1039.230 absorption associated with complex A, the star sets a lower distance limit to that HVC, and a HVC O VI component is not expected.

PG 0844+349

The wing at velocities up to 250 km s^{-1} seems to connect smoothly to the Galactic component, but after removing the H_2 J=4 line a fairly clear break can be discerned (see the apparent column density panel in Fig. 1).

The feature at 1035.380 Å (1000 km s^{-1} on the O VI velocity scale) is intrinsic Lyγ absorption (v=19372 km s^{-1}). Many Lyman lines as well as C III and O VI are seen at this velocity.

The sightline passes near the edge of the Leo Spur (v=620±160 km s^{-1}). The features at 1033.210 Å and 1033.494 Å (375 and 455 km s^{-1} on the O VI velocity scale) have strengths of 35±9 and 100±13 mÅ. If these were intergalactic Lyβ at 2190 and 2270 km s^{-1}, there should be corresponding Lyα absorption at 1224.55 and 1224.88 Å with a total equivalent width on the order of 300 mÅ. In the *FOS* spectrum of PG 0844+349 there is a 600 mÅ feature, but it lies at 1226.17 Å, or 2600 km s^{-1}. However, this is completely absent in the short (600 sec) low-resolution (150 km s^{-1} bins) *STIS* observation of PG 0844+349. There is also no room for a 300 mÅ feature near 2200 km s^{-1}.

Therefore, an alternative interpretation for the 1033.210 and 1033.494 Å features is that they are intergalactic O VI. For the higher-velocity feature the O VI λ1037.617 line overlaps the Galactic O I λ1039.230 line and is impossible to recover. For the lower-velocity feature there may possibly be an O VI λ1037.617 counterpart, but the continuum placement is uncertain, and the possible counterpart is centered at 405, rather than 375 km s^{-1}. On balance, we decided to classify the 375 and 455 km s^{-1} features as possibly being O VI. Better data for the *FUSE* SiC channels as well as a high-resolution *STIS* observations are required to exclude the possibility of Lyβ.

PG 0947+396

The LiF1A and LiF2B spectra differ substantially in this sightline, but they both show the high-positive velocity O VI component. The combined spectrum was used.

The H I spectrum in this direction is complex and shows two intermediate-velocity components, at -66 and -48 km s^{-1}. The first of these is associated with the IV16 core. However, there appears to be no O VI at the velocities of the IV H I components.

The sightline lies just 2° from PG 0953+414. The Galactic O VI column density differs little, but the HVC is 1.7 times stronger toward PG 0947+396.

The sightline passes through the Leo Spur (v=620±160 km s^{-1}) and the Leo Galaxy Grouping (v=1390±390 km s^{-1}). Weak (90 mÅ) absorption associated with the latter group may be seen at 1030.811 Å (1485 km s^{-1}, -325 km s^{-1} on the O VI velocity scale). This feature is weak enough that the corresponding Lyα line (expected to be ∼250 mÅ) does not show up clearly in the *FOS* spectrum.

The broad feature between 1033.430 and 1035.178 Å (440 to 940 km s^{-1} on the O VI velocity scale) has low significance (260±120 mÅ). It is barely visible in the LiF1A data, but adding in LiF2B strengthens it somewhat. We decided it may not be real and classify it as “unidentified”.

PG 0953+414

This is among the 10 sightlines with the highest S/N ratio (23 per resolution element). The flux varied from 7×10^{-14} erg cm^{-2} s^{-1} Å^{-1} on 1999 December 30 to 4×10^{-14} erg cm^{-2} s^{-1} Å^{-1} on 2000 May 4. This may be an intrinsic variation.

There is no clear separation between the Galactic component and the high-velocity wing. In several nearby directions such a wing is also seen, but with a clearer separation: at 100 km s^{-1} toward PG 0947+396 (2° away), at 95 km s^{-1} toward HS 1102+3441 (15° away) and at 120 km s^{-1} toward PG 0844+349 (15° away). Based on this, a velocity of 100 km s^{-1} was chosen to separate the HVC and Galactic O VI absorption.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range -100 to 100 km s^{-1} the ratio N(1037)/N(1031) is 0.99±0.011.

The identification of the feature at 1034.139 Å (645 km s^{-1} on the O VI velocity scale) remains uncertain. It is visible in both of the LiF1A and the LiF2B channels, and thus appears real. In the *STIS* spectrum there is a weak Lyα absorber at 2555 km s^{-1}with W=50 mÅ. The corresponding Lyβ feature is expected at 735 km s^{-1} on the O VI velocity scale, but with a strength of just 6 mÅ. The sightline also contains many intergalactic absorbers. For a system with z=0.05876 the C III λ977.020 line might lie at 1035.487 Å (730 km s^{-1} on the O VI velocity scale), but only Lyα (and no O VI) is found in this system. For a system with z=0.14258 C II λ903.9616 might lie at 1035.481 Å (270 km s^{-1} on the O VI velocity scale), but nothing is present there. For none of the other systems with strong Lyα do strong absorption lines end up near 1034.139 Å.

The most likely explanation for the 1034.139 Å feature is therefore that it is O VI at 645 km s^{-1}. If just the two LiF1A channels are combined it measures as 52±16 mÅ, though if the LiF2B channels are added in this is reduced to 40±12 mÅ. There appears to be a corresponding O VI λ1037.617 feature at 640 km s^{-1}, which measures as 30±14 mÅ in the LiF1A channels, and as 27±15 mÅ in the combined LiF1A+LiF2B data.

PG 1001+291

The O VI, Si II λ1020.699, Ar I λ1048.220 and C II λ1036.337 lines in the LiF2B channel look rather different than those in the LiF1A channel, so only LiF1A was used to measure O VI.

This is one of several sightlines near l=180° in which a high-positive velocity wing is seen. It was separated from the Galactic absorption by choosing to cut at a velocity of 100 $\mathrm{km\,s^{-1}}$. This is similar to the velocity at which a fairly clear separation exists in neighboring sightlines (at 100 $\mathrm{km\,s^{-1}}$ toward PG 0947+396, 11° away, at 95 $\mathrm{km\,s^{-1}}$ toward HS 1102+3441, 14° away, and at 120 $\mathrm{km\,s^{-1}}$ toward PG 0844+349, 17° away).

Although this sightline passes through the Leo Spur (v=620±160 $\mathrm{km\,s^{-1}}$), the Leo Galaxy Grouping (v=1390±390 $\mathrm{km\,s^{-1}}$) and GH51 (v=1600 $\mathrm{km\,s^{-1}}$), and there are two galaxies nearby (UGC 5340, v=441 $\mathrm{km\,s^{-1}}$, impact parameter 165 kpc, and UGCA 201=Haro 23, v=1402 $\mathrm{km\,s^{-1}}$, impact parameter 170 kpc), there is no Lyβ absorption associated with the intersected groups.

Nevertheless, there are some unidentified features in the *FUSE* and *FOS* spectra of this object. The strong line at 1028.96 Å may be Lyβ at v=945 $\mathrm{km\,s^{-1}}$, rather than H_2 J=3, as all other H_2 J=3 lines are much weaker. Further, in the *FOS* spectrum of this target (Savage et al. 2000) there are features near 1217.84 and 1223.37 Å (at velocities of 535 and 1900 $\mathrm{km\,s^{-1}}$ if they are Lyα), but these have no apparent Lyβ counterpart.

PG 1004+130

This is one of 3 sightlines where the thick disk O VI extends to more negative velocities than −120 $\mathrm{km\,s^{-1}}$ (to −130 $\mathrm{km\,s^{-1}}$), but in which there is no clear case for a separate high-velocity component. Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range −90 to 80 $\mathrm{km\,s^{-1}}$ the ratio N(1037)/N(1031) is 1.16±0.16.

Many of the H_2 J=3 lines are seen to be broad (average FWHM of 70 $\mathrm{km\,s^{-1}}$), which suggests that H_2 is present in the weak intermediate-velocity H I components. The J=4 λ1032.350 line appears present but weak. However, no independent width measurement can be obtained from other J=4 lines, so a FWHM of 70 $\mathrm{km\,s^{-1}}$ (equal to that found for the J=3 lines) was assumed to remove it from the Galactic O VI absorption.

The sightline goes through the Leo Spur (v=620±160 $\mathrm{km\,s^{-1}}$), the Leo Galaxy Grouping (v=1390±390 $\mathrm{km\,s^{-1}}$) and the Cancer-Leo Galaxy Grouping (v=2600±290 $\mathrm{km\,s^{-1}}$). The feature at 1030.136 Å (−520 $\mathrm{km\,s^{-1}}$ on the O VI velocity scale) is Lyβ at 1290 $\mathrm{km\,s^{-1}}$, as there clearly is a matching Lyα feature in the *STIS* spectrum of this object.

There are several features whose identification remains problematic. These lie at 1032.701, 1033.048, 1034.122 and 1034.644 Å (225, 325, 640 and 790 $\mathrm{km\,s^{-1}}$ on the O VI velocity scale). They cannot be O VI, as they clearly do not have counterparts in the O VI λ1037.617 line. They are very unlikely to be Lyβ, as no strong Lyα absorption is seen at corresponding velocities. The most likely possibility seems to be that they are several instances of O III λ832.927 at a redshift of 0.2398 to 0.2422, as the redshift of PG 1004+130 itself is 0.2400. The velocities and relative strengths of these features are inconsistent with an interpretation as redshifted O II $\lambda\lambda$832.757, 833.329, 834.466. The Galactic O VI absorption seems unaffected by redshifted O III, since the

$N_a(v)$ profiles of the O VI λ1031.926 and O VI λ1037.617 lines agree very well.

PG 1048+342

Several galaxies in the Leo Galaxy Grouping (v=1390±390 km s^{-1}) lie close to this sightline: NGC 3442 (v=1713 km s^{-1}, 20 arcmin, impact parameter 160 kpc), NGC 3430 (v=1533 km s^{-1}, 1°, impact parameter 490 kpc), NGC 3395 and NGC 3396 (v=1595 and 1649 km s^{-1}, 1°.1, impact parameter 525 kpc). Lyβ absorption from the group is seen at about 1031.6 Å (v=1720 km s^{-1}, −90 km s^{-1} on the O VI velocity scale), which overlaps the Galactic O VI and makes it impossible to measure. That this feature is Lyβ follows from the combination of facts that it is very strong, while no O VI λ1037.617 counterpart can be seen.

PG 1116+215

This is one of the many sightlines near l=180° with high-positive velocity O VI. In this case the Galactic and HVC component are clearly separated and the HVC component (also visible in the O VI λ1037.617 line) shows internal structure. Two separate HVC components were measured. There is no contamination by H_2 J=4 apparent.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range −55 to 90 km s^{-1} the ratio N(1037)/N(1031) is 1.09±0.13, while in the velocity range 150 to 230 km s^{-1} this ratio is 1.08±0.16.

This is one of the sightlines for which assuming that the H I is centered around 0 km s^{-1} would yield an erroneous alignment; the strongest H I component is at −40 km s^{-1}. Assuming that it is at 0 km s^{-1} might lead to the conclusion that there is high-velocity C II, but not C II*.

Although the sightline passes through the edge of the Leo Galaxy Grouping (v=1390±390 km s^{-1}), the feature at 19 km s^{-1} cannot be intergalactic Lyβ – the corresponding Lyα line is clearly absent in the *STIS* spectrum. Lyα lines are detected at velocities of 960 and 1480 km s^{-1}, but these are so weak that the corresponding Lyβ lines are undetectable. The two features at 1028.813 and 1029.171 Å (−905 and −800 km s^{-1} on the O VI velocity scale) are intergalactic C II λλ903.6235, 903.9616 in a system at z=0.138 in which many lines are found.

PG 1211+143

The spectrum in the LiF2B channel differs in many ways from that in the LiF1A channel. For the O VI λ1031.926 line there is a broad ∼200 km s^{-1} wide depression which is centered around 1035 Å. The LiF2B and SiC2A channels also differ. Since the LiF1A channel appears to behave normally, only that channel was used for the measurements.

Similar to the neighbouring direction toward Mrk 734, the O VI absorption at negative velocities is weak.

The sightline passes through the Virgo Cluster, with NGC 4212 (v=−163) and NGC 4189 (v=2039 km s^{-1}) having impact parameters of 105 and 185 kpc, respectively. The 3σ feature centered at 1032.938 Å (295 km s^{-1} on the O VI velocity scale) is probably Lyβ at 2110 km s^{-1} associated with the Virgo Cluster (v=1360±720 km s^{-1}), as there is a Lyα line at 2115 km s^{-1} in the *STIS* spectrum. On the other hand, the feature at 1033.393 Å (425 km s^{-1} on the O VI velocity scale) cannot be Lyβ. Furthermore, although there are 13 Lyα absorbers visible in the *STIS* spectrum, none of these is at a redshift such that other Lyman lines, O VI, C III or low-ionization lines fall near 1033 Å. There is a possibility that it is O VI, but the corresponding O VI λ1037.617 line would be hidden by low-velocity O I λ1039.230 absorption. We therefore classify it as "unidentified".

The feature at 1035.203 Å is intergalactic Lyγ at 19315 km s^{-1} (z=0.0680). Lyα to Lyη, C III and O VI are found in this system.

The redshift of PG 1211+143 is given as 0.08090 in *NED*. However, this is based on a fit to an asymmetric C IV profile at 1650 Å. From the intrinsic Lyman lines it is clear that the redshift actually is 0.08040.

PG 1216+069

There is a Lyman series at v=1880 km s^{-1} in this spectrum, associated with the Virgo Cluster. The Lyα line can be seen in the *FOS* spectrum (Savage et al. 2000). The Lyβ line in this series overlaps the Galactic O VI component. This makes it impossible to measure the Galactic O VI λ1031.926 absorption. The Galactic O VI λ1037.617 is not clearly seen either. It is still possible to discern a high-velocity O VI component in the O VI λ1031.926 and O VI λ1037.617 lines (near 290 km s^{-1}), whose presence would be consistent with other similar components seen in neighbouring directions (3C273.0, HE 1228+0131, PG 1116+215, Mrk 734).

PG 1259+593

This is the sightline with the highest S/N ratio (30 per resolution element), and the second longest *FUSE* observation (633 ks).

It is one of 9 sightlines which show O VI absorption associated with HVC complex C, and one of the clearest complex C components. Richter et al. (2001b) analyze the low-ionization absorption lines in complex C and the IV-Arch. There is also a high-velocity O VI wing at positive velocities (140 km s^{-1}), although this is a weak non-gaussian component (optical depth <0.03) that integrates to a 2.3σ detection. This cannot be intergalactic Lyβ since there is no corresponding Lyα absorption at 1223.699 Å in the *STIS* spectrum of PG 1259+593.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range -60 to 100 km s^{-1} the ratio N(1037)/N(1031) is 1.29±0.11, showing that some saturation is present.

The sightline passes through the Ursa Major Galaxy Grouping (v=1360±540 km s^{-1}) and the Canes Venatici Galaxy Grouping (v=2360±330 km s^{-1}). The feature at 1033.578 Å (480 km s^{-1} on the O VI velocity scale) is inter-group Lyβ at 2295 km s^{-1}. The Lyα line is clearly seen at 1224.902 Å in the *STIS* spectrum of PG 1259+593.

The galaxy (UGC 8146; v=669 km s^{-1}) in the closer Ursa Major Galaxy Grouping lies just 22 arcmin away (90 kpc impact parameter), and associated Lyα and Lyβ absorption is seen at corresponding velocities. There may even be O VI absorption at similar velocities. Three weak ($\sim$25 mÅ) features appear at 1034.124, 1034.386 and 1034.714 Å (640, 715 and 810 km s^{-1} on the O VI velocity scale). The corresponding O VI λ1037.617 absorption is confused with O I* emission lines, but in the smoothed orbital-night-only data there may be a 2σ feature.

PG 1302−102

This object has a wavy continuum, so that it is necessary to fit a 5th order polynomial. This makes the continuum near the O VI λ1037.617 line too uncertain to confidently compare the O VI λ1031.926 and O VI λ1037.617 column densities.

The sightline passes through the Virgo Cluster (v=1360±720 km s^{-1}), but although there are several features that might be Lyβ, none can be confirmed. In particular, the identification of the feature at 1030.237 Å ($-$490 km s^{-1} on the O VI velocity scale) remains tentative. If it is Lyβ at 1320 km s^{-1} associated with the Virgo Cluster, there should be a 500 mÅ Lyα line at 1221.022 Å, but this is not seen clearly in the *FOS* spectrum (Savage et al. 2000). The corresponding Lyγ line is blended with C III λ977.020, which falls at v=1375 km s^{-1} on the Lyγ velocity scale. The C III absorption seems to have a wing at v(Lyγ)$\sim$1300 km s^{-1}, however, which is where the intergalactic Lyγ would be expected.

The feature at 1032.804 Å (255 km s^{-1} on the O VI velocity scale) is most likely high-velocity O VI, as there appears to be a corresponding feature in the O VI λ1037.617 line, and in many sightlines in the neighbourhood of PG 1302$-$102 high-positive velocity O VI is also found (e.g. HE 1115$-$1735, IRAS F11431$-$1810, 3C273.0). This feature might be Lyβ at v=2070 km s^{-1}, but from the *FOS* spectrum it is not clear whether there is corresponding Lyα. A *STIS* spectrum of this target has been taken, but is not yet public data.

The apparent structure in the high-velocity component is caused by noise peaks in the shorter observations.

This spectrum is particularly rich in Lyman systems. There are systems at z=0.09397 and 0.09484 (both in Lyα to Lyη, both showing C III), at z=0.14537 (Lyα, Lyβ, as well as a weak C II λ903.9616 at 1035.482 Å, 1033 km s^{-1} on the O VI velocity scale) and at z=0.19160 (Lyα through Lyζ. Another system near z=0.097 is less clear in just Lyα and Lyβ. In none of these systems do H I, C III, or low-ion lines fall near Galactic O VI.

PG 1307+085

This sightline passes through the outer edge of the Virgo Cluster (v=1360±720 km s^{-1}), and 190 kpc from UGC 8091 (v=165 km s^{-1}). However, no associated intergalactic absorption can be discerned.

PG 1351+640

This is one of two sightlines where intermediate-velocity H_2 J=3 contaminates the O VI spectrum (Mrk 357 being the other). It is also one of 9 sightlines in which O VI absorption associated with complex C is seen. The Galactic and HVC O VI components are separated at a velocity of $-$100 km s^{-1}, as there are no clear components visible.

The amount of contamination due to H_2 J=4 is unclear. Other J=4 lines of similar strength are either confused with other H_2 lines or in a part of the spectrum with low S/N ratio. Lines in clearer regions are a factor 2 weaker and absent. The tabulated Galactic O VI column density assumes that there is no contamination. A cut was placed at 100 km s^{-1} to separate the weak (3σ) positive-velocity wing from the Galactic absorption.

The sightline passes through the Canes Venatici Galaxy Grouping (v=2360±330 km s^{-1}), and there are two galaxies within 1°(UGC 8894, v=1943 km s^{-1}, and Mrk 277, v=1828 km s^{-1}), but both have an impact parameter of 320 kpc and there does not appear to be Lyβ absorption associated with the galaxy group.

The absorptions centered at 1029.991 and 1030.760 Å (-560 and -340 km s^{-1} on the O VI velocity scale) are Lyδ in two absorption systems at 25330 and 25575 km s^{-1} (z=0.08449 and 0.08531), which are associated with PG 1351+640. Corresponding Lyβ, Lyγ, Lyϵ C III and O VI are also visible. Considering the extent of the Lyγ and Lyϵ lines, the Lyδ line should extend to $\sim$1030.83 Å, or -320 km s^{-1} on the O VI velocity scale. It does not contaminate the Galactic O VI absorption.

PG 1352+183

The sightline passes 20 arcmin (135 kpc) from UGC 8839 (v=971 km s^{-1}), which lies at the very edge of the Virgo-Libra Galaxy Grouping (v=1820$\pm$490 km s^{-1}). The feature at 1029.933 Å (-580 km s^{-1} on the O VI velocity scale) may be Lyβ at 1230 km s^{-1} associated with UGC 8839.

PG 1402+261

This sightline passes through the Canes Venatici Spur (v=1140$\pm$250 km s^{-1}), but no intergalactic absorption is seen. The O VI profile is simple and clear.

PG 1404+226

This spectrum has a S/N ratio near the limit (3.2 per resolution element).

The feature at 1030.516 Å (-410 km s^{-1} on the O VI velocity scale) is intrinsic Lyϵ absorption at z=0.09886.

The sightline passes 90 kpc from UGC 9128 (v=196 km s^{-1}), but no apparent associated absorption can be discerned near O VI λ1031.926.

PG 1411+442

This sightline passes about 5° north of HVC complex C. The continuum placement and the negative-velocity extent of the thick disk O VI do not seem to be adversely affected by the presence of the absorption centered at 1029.861 Å (-600 km s^{-1} on the O VI velocity scale), which is intrinsic Lyδ absorption at z=0.08436.

This sightline passes near the edges of the Draco Galaxy Grouping (v=1120$\pm$390 km s^{-1}), the Canes Venatici Spur (v=1140$\pm$250 km s^{-1}) and the Canes Venatici Galaxy Grouping (v=2360$\pm$330 km s^{-1}), while UGC 9240 (v=281 km s^{-1}) lies 130 kpc away. No associated intergalactic Lyβ is visible within 1200 km s^{-1} of O VI λ1031.926.

The feature at 1034.674 Å may be intergalactic O VI at 800 km s^{-1} rather than intergalactic Lyβ at 2620 km s^{-1}, because the Lyα absorption is not clear at this velocity in the *FOS* spectrum (although it has low S/N ratio). A possible counterpart for O VI is seen in the O VI λ1037.617 line near 1040.455 Å, although the spectrum is noisy and this feature is offset in velocity by 20 km s^{-1}. Associated Lyδ at v=25320 km s^{-1} is found at about 1030.5 Å (-600 km s^{-1} on the O VI velocity scale; -1600 km s^{-1} relative to PG 1411+442).

This is also one of a close triplet of sightlines in our sample. SBS 1415+437 lies 46 arcmin away, and PG 1415+451 is at 65 arcmin (the angular distance between the latter two is 85 arcmin). This triplet clearly illustrates the large changes that can occur in W(O VI) on small angular scales. Toward PG 1411+442 a deep (65% absorption) O VI profile ranges from -95 to 90 km s^{-1}, with W= 303±30 mÅ. Toward PG 1415+451 the O VI profile (55% absorption) ranges from −80 to 100 km s^{-1}, with W= 200±42 mÅ. Toward SBS 1415+437 the O VI is much shallower (35% absorption) and ranges from −50 to 100 km s^{-1}, with W= 145±39 mÅ.

PG 1415+451

The LiF1A and LiF2B spectra differ for this object. LiF1A shows a fairly narrow central O VI absorption with an extended positive-velocity wing, whereas LiF2B is shallower, and the positive-velocity wing is not as clear. The combined spectrum was still used.

The feature centered at 210 km s^{-1} is a 3.0σ, and appears to be real. It is likely that this is Lyγ at z=0.0618 (18525 km s^{-1}), as there are matching features at the wavelengths corresponding to Lyα, Lyβ and possibly Lyδ. All these features are ∼2–3σ, but they match if log N(H I)=14.9±0.6 and b=12^{+17}_{-6} km s^{-1}.

This sightline passes near the edges of the Draco Galaxy Grouping (v=1120±390 km s^{-1}), the Canes Venatici Spur (v=1140±250 km s^{-1}) and the Canes Venatici Galaxy Grouping (v=2360±330 km s^{-1}). UGC 9240 (v=281 km s^{-1}) lies 90 kpc away. No intergalactic Lyβ is visible. See also the notes to PG 1411+442 about the triplet of sightlines of which PG 1415+451 is a part.

PG 1444+407

The feature at 1034.913 Å (870 km s^{-1} on the O VI velocity scale) is Lyβ at 2685 km s^{-1}, as there is a Lyα counterpart of the proper strength in the *FOS* spectrum. There is a small group of nine galaxies nearby: the Bootes Galaxy Grouping (v=2650±310 km s^{-1}), although the closest galaxy (I Zw 97; v=2669 km s^{-1}) lies 2° away (1.4 Mpc impact parameter).

The 90 mÅ feature at 1031.096 Å (−240 km s^{-1} on the O VI velocity scale) is a 3.0σ detection. It is unlikely to be O VI since there is no counterpart in the O VI λ1037.617 line, which would fall between the Galactic C II λ1036.337 and C II* λ1037.018 lines. If it is intergalactic Lyβ at 1570 km s^{-1}, the corresponding Lyα line at 1222.035 Å is not clearly visible in the *FOS* spectrum of this object, though its presence is not excluded.

PG 1626+554

This is one of 9 sightlines toward which O VI associated with HVC complex C is seen. The absorption near −210 km s^{-1} mimics a H_2 J=3 line, but no evidence is seen for any of the other J=3 lines. Similarly, no evidence is seen for any J=4 H_2 lines, which implies that the feature at 140 km s^{-1} is high-positive-velocity O VI. The −150 km s^{-1} component is the strongest of the 9 complex C components (W=220±37 mÅ).

This sightline passes just 13 kpc from the Draco dwarf spheroidal (v=−31 km s^{-1}), which has a 1.8 kpc diameter. Strong corresponding absorption is not evident, but weak absorption would be hidden in the Galactic profile.

PG 2349−014

The Galactic O VI absorption is very weak; the 3σ upper limit for the −70 to 70 km s^{-1} velocity range is 120 mÅ (log N(O VI)<13.97). Two clear high-negative velocity components are present, dissected by a very strong H_2 J=3 line. This is one of three sightlines where high-negative velocity H I (v=−300 km s^{-1}) in the tip of the Magellanic Stream is also detected. The relation with the high-velocity O VI is unclear.

The identity of the feature at 1032.537 Å (180 $\mathrm{km\,s^{-1}}$ on the O VI velocity scale) is unclear. It measures as 2.6σ, but it seems real. It is most likely Lyβ at 1990 $\mathrm{km\,s^{-1}}$, even though the nearest galaxies with similar velocities have an impact parameter of 3 Mpc. In the low-resolution (300 $\mathrm{km\,s^{-1}}$) *STIS* snapshot a possible Lyα match can be discerned.

C II absorption is seen at a velocity of -290 $\mathrm{km\,s^{-1}}$, with W=245$\pm$37 mÅ. An H I component with N(H I)=3.0$\times 10^{18}$ $\mathrm{cm^{-2}}$ is seen in the Green Bank spectrum, with a FWHM of 49 $\mathrm{km\,s^{-1}}$. This is compatible with the C II absorption for gas with Magellanic abundances.

PHL 1811

This sightline has a Lyman limit system at z=0.08088 (985 Å). There are also absorption systems at z=0.07339, 0.07774, 0.07895, 0.13220, 0.13536 and 0.17645. None of these systems yield lines that can interfere with the Galactic O VI absorption; the wavelength range of the z$\sim$0.08 system is redshifted to 1031–1033 Å is 954–962 Å and the only strong interstellar line in this range is N I λ954.104. In the system at z=0.08088, this line would be at v=$-$210 $\mathrm{km\,s^{-1}}$ on the O VI LSR velocity scale. However, in that case the O I λ988.773 line should be very strong (the optical depth ratio O I λ988.773/N I λ954.104 is $\sim$100), but only a weak O I λ988.773 line is seen..

NED lists the redshift of this object as 0.190, even though the original publication (Leighly et al. 2001) lists 0.192.

C II absorption is seen at a velocity of -195 $\mathrm{km\,s^{-1}}$, with W=200$\pm$24 mÅ. The Leiden-Dwingeloo Survey H I spectrum sets an upper limit on N(H I) at this velocity of $\sim$4$\times 10^{18}$ $\mathrm{cm^{-2}}$. Assuming that the b-value is large, this is compatible with the C II absorption for gas with Magellanic abundances, even though this sightline lies 15° away from where the Stream is detected in H I 21-cm emission.

PKS 0405$-$12

This QSO has a flat continuum and high S/N ratio. The weak Galactic O VI is clearly seen, as is a weak positive-velocity wing.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range -40 to 50 $\mathrm{km\,s^{-1}}$ the ratio N(1037)/N(1031) is 0.96$\pm$0.21.

The sightline passes through the outskirts of the Dorado Galaxy Grouping (v=970$\pm$250 $\mathrm{km\,s^{-1}}$), but no Lyβ is seen. There is a Lyman limit system at z=0.167, in which many metal lines can be seen.

PKS 0558$-$504

This is one of 2 sightlines where the thick disk O VI extends to more positive velocities than 120 $\mathrm{km\,s^{-1}}$ (to 135 $\mathrm{km\,s^{-1}}$), but in which there is no clear case for a separate high-velocity component. Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range -100 to 100 $\mathrm{km\,s^{-1}}$ the ratio N(1037)/N(1031) is 1.13$\pm$0.15.

The sightline also passes through the Dorado Galaxy Grouping (v=970$\pm$250 $\mathrm{km\,s^{-1}}$), but no intergalactic Lyβ can be discerned.

This sightline passes only about 2° from HVC WW425, a cloud with v=260 $\mathrm{km\,s^{-1}}$, which may be part of the Magellanic Stream. The high-positive velocity O VI feature may be associated with that HVC.

PKS 2005−489

A HVC component similar to the one at 155 $\mathrm{km\,s^{-1}}$ is seen toward ESO 141−G55, which lies 12° away. Judging from the shape of the wing of the O VI λ1037.617 line this feature does seem to be high-velocity O VI. It is not clear where to cut the HVC and Galactic components, but there seems to be a discontinuity near 120 $\mathrm{km\,s^{-1}}$.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range −50 to 120 $\mathrm{km\,s^{-1}}$ the ratio N(1037)/N(1031) is 0.94±0.07.

The sightline passes within 400 kpc of a subgroup of 5 galaxies in the Telescopium-Grus Galaxy Grouping (v=2030±500 $\mathrm{km\,s^{-1}}$). Intergalactic Lyβ may be present. However, if such a line contaminates the O VI line, the corresponding Lyγ line is too weak to discern. There is a Lyman series at v=5075 $\mathrm{km\,s^{-1}}$ in this spectrum, in which Lyβ, Lyγ, Lyδ and C III are seen.

PKS 2155−304

This is among the 10 sightlines with the highest S/N ratio (27 per resolution element). There are three observations, with differing fluxes. On 1999 October 23/24 the flux was 17×10^{-14} $\mathrm{erg\,cm^{-2}\,s^{-1}\,Å^{-1}}$, while on 2001 June 18 the flux was 11×10^{-14} $\mathrm{erg\,cm^{-2}\,s^{-1}\,Å^{-1}}$. This change is probably intrinsic to PKS 2155−304.

There is no H_2 present in this sightline, so the absorption between −280 and −85 $\mathrm{km\,s^{-1}}$ is all O VI. The separation between the HVC and Galactic absorption is based on the fact that in most nearby sightlines Galactic absorption extends to about −85 $\mathrm{km\,s^{-1}}$ (see Sect. 4.1.3 point d).

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range −70 to 120 $\mathrm{km\,s^{-1}}$ the ratio N(1037)/N(1031) is 1.05±0.07.

The sightline passes through the Pisces Austrinis Spur (v=2590±260 $\mathrm{km\,s^{-1}}$), but no intergalactic Lyβ is visible.

C II absorption is seen at a velocity of −130 $\mathrm{km\,s^{-1}}$, with W=48±7 mÅ, or N(C II)$\sim5\times10^{13}$ $\mathrm{cm^{-2}}$. Assuming carbon is not depleted on dust, this corresponds to N(H I)=0.2×10^{17}/Z $\mathrm{cm^{-2}}$, with Z the metallicity in solar units. The Green Bank spectrum sets a 3σ upper limit of $\sim2\times10^{18}$ $\mathrm{cm^{-2}}$ on N(H I).

SBS 0335−052

The Galactic O VI absorption is very weak. Only a 3σ upper limit of 120 mÅ (log N(O VI)<13.98) can be set. The intrinsic Lyβ absorption (centered at 4050 $\mathrm{km\,s^{-1}}$ or 1039.5 Å) provides a fairly smooth continuum. Low Galactic O VI column densities are also seen in several other nearby sightlines (NGC 1068, Mrk 618, Mrk 1095 and PKS 0405−12).

SBS 1415+437

On the LiF1 side, only 3 of the 12 exposures have signal. Thus, the LiF2B channel has a better S/N ratio than LiF1A.

This sightline passes near the edges of the Draco Galaxy Grouping (v=1120±390 $\mathrm{km\,s^{-1}}$), the Canes Venatici Spur (v=1140±250 $\mathrm{km\,s^{-1}}$) and the Canes Venatici Galaxy Grouping (v=2360±330 $\mathrm{km\,s^{-1}}$). UGC 9240 (v=281 $\mathrm{km\,s^{-1}}$) lies 110 kpc away. No intergalactic Lyβ is visible near these velocities. See also the notes to PG 1411+442 about the triplet of sightlines of which SBS 1415+437 is a part.

Tol 0440−381

The emission-like feature at the short wavelength side of the O VI absorption is troublesome. It occurs in both the LiF1A and the LiF2B channels, and is present in both the orbital day and orbital night data. It is not at the redshift of an absorption system. If it were intrinsic to Tol 0440−381 it is emission at about 990 Å, in the wavelength region near N III, O I and Si II, which makes this unlikely. In any case, this feature makes the extent of the Galactic O VI absorption too difficult to determine and we did not include this sightline in the final sample.

Tol 1247−232

Near the O VI line the continuum placement for this source is slightly problematic. Over the 1010–1050 Å range the continuum is on average rather flat. However, on the short wavelength side of the O VI line the level is higher than on the long wavelength side. On larger scales, the continuum is closer to that on the positive-velocity side, so the high continuum near -300 km s^{-1} was ignored in the fitting. This may lead to an underestimate of W(O VI).

The high-velocity O VI component was separated from the thick disk absorption at a velocity of 100 km s^{-1}, even though there is no clear boundary visible in the spectrum. The separation velocity is based on other sightlines in this region of the sky that have high-velocity absorption (the closest are ESO 572−G34, 13° away, and Mrk 1383, 35° away).

Tol 1924−416

The LiF1A and LiF2B spectra look different, although this may mostly be due to low S/N ratio in the LiF2B channel. The main difference is that the H_2 J=3 line seems absent in LiF1A, but strong in LiF2B.

There does not appear to be high-velocity O VI in this direction, even though such absorption is seen toward all other sightlines within about 30° (ESO 141−G55, PKS 2005−489 and Mrk 509).

Intrinsic Si II λ1020.699 absorption at v=2825 km s^{-1} can be seen at 1030.322 Å (-465 km s^{-1} on the O VI velocity scale)

Ton 1187

The LiF1A and LiF2B spectra are both noisy and show some differences, but these are still within the noise.

This is the only sightline in which HVC complex M is clearly visible in H I emission (at $v_{\rm LSR}$=-104 km s^{-1}). There does not appear to be O VI absorption at this velocity, however.

Ton S180

The LiF2B channel has a much lower apparent flux than LiF1A, most likely because it was misaligned in this early observation. Only LiF1A was used.

The intrinsic Lyγ absorption line at v=18580 km s^{-1} is expected to lie at 1032.814 Å (260 km s^{-1} on the O VI velocity scale). However, there is no matching Lyβ absorption, although intrinsic O VI at v=18700 km s^{-1} is clearly present.

This sightline passes 110 kpc from NGC 247 (v=190 km s^{-1}, distance 2.1 Mpc), 145 kpc from

UGCA 15 (v=331 km s^{-1}) and 200 kpc from NGC 253 (v=260 km s^{-1}), all of which lie in the Coma-Sculptor Galaxy Grouping (v=420±300 km s^{-1}). The Lyβ line shows a positive-velocity wing out to ∼200 km s^{-1}.

Considering the points above, the 48±12 mÅ feature at 1032.787 Å (250 km s^{-1} on the O VI velocity scale) appears to be high-velocity O VI rather than an intrinsic absorption line or intergalactic Lyβ. A weak (2σ) matching O VI λ1037.617 line appears present, with equivalent width 22±13 mÅ(i.e., the strength is about that expected from the possible O VI λ1031.926 feature). No other sightlines in this part of the sky show high-positive velocity O VI.

C II absorption is seen at a velocity of −130 km s^{-1}, with W=52±18 mÅ, or N(C II)∼6×10^{13} cm^{-2}. Assuming carbon is not depleted on dust, this corresponds to N(H I)=0.2×10^{17}/Z cm^{-2}, with Z the metallicity in solar units. The Green Bank spectrum sets a 3σ upper limit of ∼2×10^{18} cm^{-2} on N(H I).

Ton S210

The LiF2B channel of the first observation was misaligned and shows no flux.

This sightline passes within 15 arcmin of (or even through) a HVC which has v=−190 km s^{-1}. Sembach et al. (2002a) discuss this sightline. C II λ1036.337 absorption is detected at −170 km s^{-1}, and is probably associated with the outer envelope of the HVC. The high-negative velocity O VI component centered at −185 km s^{-1} may trace an outer ionized envelope of this HVC, or it may be part of a more general distribution of high-velocity O VI seen in this part of the sky (it is possible that both the high-velocity H I and O VI originate in the same manner).

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range −90 to 95 km s^{-1} the ratio N(1037)/N(1031) is 0.98±0.10.

C II absorption is seen at a velocity of −175 km s^{-1}, with W=230±13 mÅ. The Effelsberg spectrum sets an upper limit of 3×10^{18} cm^{-2} for H I at this velocity. For gas with Magellanic abundances this is compatible with the C II absorption, if the b-value is large.

UGC 12163 (Akn 564)

During the 61.6 ks observation, the source was misaligned on detector side 1 for the first 8 of the 32 exposures, effectively reducing the exposure time to 40 ks.

The Galactic O VI is very weak in this direction. In the velocity range between −100 and 100 km s^{-1} the absorption integrates to 107±32 mÅ, corresponding to a 3.3σ detection. A high-negative velocity O VI component is also present, whose positive-velocity edge is contaminated by H_2 J=3.

The absorption features at 1034.990 and 1035.677 Å (890 and 1090 km s^{-1} on the O VI velocity scale) are most likely interstellar C II λ1036.337 at −390 and −190 km s^{-1}. The Lyβ and Lyγ lines show extended negative-velocity wings, while there is a separate feature in Lyδ. This gas is probably associated with the Magellanic Stream. In H I emission the tip of the Stream is about 10° away, and points in the direction of UGC 12163. The equivalent widths of the C II features are 160±34 and 98±27 mÅ, corresponding to N(C II) ∼10^{14} cm^{-2}. This is compatible with the upper limit for N(H I) of ∼5×10^{18} cm^{-2}.

The sightline passes through the Pegasus Galaxy Grouping (v=2170±480 km s^{-1}), but no

Lyβ is visible.

VII Zw 118

Although the continuum seems well defined, the comparison between the 1031 and 1037 N_a(v) profiles indicates either a problem or the presence of saturation. However, the H_2 column density is large enough that the H_2 J=1 λ1037.146 line has damping wings that may shift the continuum down near the O VI λ1037.617 line.

The feature at 1034.104 Å (630 km s^{-1} on the O VI velocity scale) is intergalactic Lyβ at v=2450 km s^{-1}. The corresponding Lyα line can be seen in the *STIS* spectrum. However, no galaxy groups are intersected by this sightline. The nearest group (>3° or 1.5 Mpc impact parameter away) is the Lynx Galaxy Grouping (v=1850±280 km s^{-1}). The nearest galaxies in this group have v=1900 km s^{-1}, much less than the 2450 km s^{-1} of the intergalactic absorption. MS 0700.7+6338 lies 1° closer to the Lynx Galaxy Grouping, but no Lyβ is seen in its spectrum.

vZ 1128

This is the sightline with the second highest S/N ratio (29 per resolution element).

vZ 1128 is a star in the globular cluster M 3, which lies at a distance of 9.7 kpc (z=9.5 kpc).

The alignment of this spectrum relative to the H I is slightly problematic. Howk et al. (2002) use v2.0.5 of the pipeline and argue that the shape of the Ar I and O I lines fits the H I quite well. This implies that the Si II line is shifted, and that there is C II absorption at velocities up to 30 km s^{-1} more negative than the H I. We use the same alignment as Howk et al. (2002), but this shifts the spectrum by −20 km s^{-1} relative to a determination that would be based on just the shape of the Ar I and Si II absorption as seen in the v1.8.7 version of the spectrum. This sight line and that for 3C 273.0 illustrate the substantial problems associated with determining the velocity offsets in *FUSE* spectra.

Both the O VI λ1031.926 and the O VI λ1037.617 lines can be measured. In the velocity range −130 to 80 km s^{-1} the ratio N(1037)/N(1031) is 0.97±0.05.

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Figure 2.. Four examples showing the shift required to align the apparent column density profiles of the O VI λ1031.926 and O VI λ1037.617 lines. For each of the four objects, the two left panels shows the $N_a(v)$ profiles using the nominal wavelength calibration, the two right panels show them after shifting O VI λ1037.617 by 10 $\mathrm{km\,s^{-1}}$. The top panel give the O VI λ1031.926 line is shown as a thick line, the O VI λ1037.617 line as a thin line, while the bottom panel present the ratio of the two profiles, slightly smoothed by a gaussian with a FWHM of 2 pixels. Over the uncontaminated velocity range defined by the heavy vertical lines on the spectra, the ratio clearly shows an unphysical slope before applying the velocity correction.

Figure 3.. Comparison of the flux observed with *FUSE* to the flux expected from an extrapolation of the *IUE* spectrum to 1030 Å. Star symbols are for QSOs, closed circles for Seyfert galaxies and open circles for other kinds of galaxies. The horizontal and vertical lines in the top panel are drawn at a level of $2{\times}10^{-14}$ $\mathrm{erg\,cm^{-2}\,s^{-1}}$ $\mathrm{Å^{-1}}$; the diagonal line shows the 1–1 relationship.

Figure 4.. Comparison of the visual and blue magnitudes from the Véron-Cetty & Véron catalogue (2000) with the flux observed near 1030 Å, separately for QSOs, Seyferts and galaxies. The symbols indicate the reddening, E(B−V), which is almost always <0.07 mag. A reddening of 0.04 mag corresponds to a reduction in flux of a factor $\sim$1.6, a shift of 0.2 in the log. The correlation coefficient, ρ, is indicated in the top right corner of each panel. The horizontal lines indicate a flux of $5{\times}10^{-15}$ $\mathrm{erg\,cm^{-2}\,s^{-1}}$ $\mathrm{Å^{-1}}$, below which the measured fluxes are unreliable.

Figure 5.. Histograms of the number of objects for which the O VI absorption extends out to a velocity $v_{\rm min}$ or $v_{\rm max}$. Thin lines include all sightlines, thick lines exclude 26 sightlines where the separation of Milky Way and high-velocity absorption is difficult and eleven upper limits. Top panel: velocity limits for the Milky Way component. Middle panel: most-negative velocity edge for the HVC component. Bottom panel: most-positive velocity edge for the HVC component.

Figure 6.. Histograms of the equivalent widths and their errors. The top set of panels is for Milky Way O VI absorption (mostly between $\pm$120 $\mathrm{km\,s^{-1}}$). The bottom set of panels is for high-velocity O VI. The quality factor Q for a row of histograms is indicated at the right hand edge. The four columns of four panels give, from left to right, the equivalent width, the error associated with random noise ($\sigma_{\rm W,noise}$), the error associated with fitting the continuum ($\sigma_{\rm W,cfit}$) and the error associated with choosing an integration range ($\sigma_{\rm W,vlim}$).

Figure 7.. Correlations between the random-noise error ($\sigma_{\rm W,noise}$), the continuum-fit error ($\sigma_{\rm W,cfit}$), the error in the continuum fit calculated by shifting the continuum up or down by $\sigma_{\rm W,noise}/3$ ($\sigma_{\rm W,rms/3}$) and the velocity-limits error ($\sigma_{\rm W,vlim}$). Plus signs indicate local continuum fits with polynomial order 1, filled circles are for local continuum fits with order 2; open circles are

for the 15 fits with higher orders. The solid lines show least-squares fits, separately for the fits with order 1 and order 2.

Figure 8.. The upper panel shows the ratio (and its error) for the column densities derived from the two O VI lines, in the velocity range where the O VI λ1037.617 absorption can be reliably measured. The error includes the effect of random noise and continuum placement uncertainty, but not the contributions to the systematic error. The vertical axis gives the rank of the object after sorting on ratio. In the lower panel the ratios are plotted against the column density derived from the O VI λ1031.926 line.

Figure 9.. Top panels (a, h); scatter plots of O VI column density against average component velocity, with symbol sizes proportional to the b-value. Panels b to g (left) show the number of high-velocity O VI absorbers in 25 $\mathrm{km\,s^{-1}}$ intervals, for a series of equivalent width ranges. Panels i to m (right) give the distribution of the low-velocity Galactic O VI absorbers, in 4 $\mathrm{km\,s^{-1}}$ intervals.

Figure 10a.. O VI column density for 10 sightlines (and 23 significant non-detections), integrated from $v_{\rm LSR}$=−500 to −300 $\mathrm{km\,s^{-1}}$, in an aitoff projection of galactic coordinates, with the galactic Anti-Center in the middle. The dots indicate all sightlines toward which a measurement was obtained, surrounded by a 12° radius colored area. Stronger mottling indicates sightlines with lower S/N ratios. Upper limits are shown by a colored area $2\overset{\circ}{.}5$ in diameter. See Sect. 5.5 for more details.

Figure 10b.. O VI column density for 18 sightlines (and 20 significant non-detections), integrated from $v_{\rm LSR}$=−300 to $v_{\rm LSR}$=−200 $\mathrm{km\,s^{-1}}$.

Figure 10c.. O VI column density for 20 sightlines (and 17 significant non-detections), integrated from $v_{\rm LSR}$=−200 to $v_{\rm LSR}$=−150 $\mathrm{km\,s^{-1}}$.

Figure 10d.. O VI column density for 32 sightlines (and 12 significant non-detections), integrated from $v_{\rm LSR}$=−150 to $v_{\rm LSR}$=−100 $\mathrm{km\,s^{-1}}$.

Figure 10e.. O VI column density for 56 sightlines (and 4 significant non-detections), integrated from $v_{\rm LSR}$=−100 to $v_{\rm LSR}$=−50 $\mathrm{km\,s^{-1}}$.

Figure 10f.. O VI column density for 79 sightlines, integrated from $v_{\rm LSR}$=−50 to $v_{\rm LSR}$=−0 $\mathrm{km\,s^{-1}}$.

Figure 10g.. O VI column density for 83 sightlines, integrated from $v_{\rm LSR}$=0 to $v_{\rm LSR}$=50 km s^{-1}.

Figure 10h.. O VI column density for 54 sightlines (and 4 significant non-detections), integrated from $v_{\rm LSR}$=50 to $v_{\rm LSR}$=100 km s^{-1}.

Figure 10i.. O VI column density for 26 sightlines (and 14 significant non-detections), integrated from $v_{\rm LSR}$=100 to $v_{\rm LSR}$=150 km s^{-1}.

Figure 10j.. O VI column density for 16 sightlines (and 17 significant non-detections), integrated from $v_{\rm LSR}$=150 to $v_{\rm LSR}$=200 km s^{-1}.

Figure 10k.. O VI column density for 13 sightlines (and 20 significant non-detections), integrated from $v_{\rm LSR}$=200 to $v_{\rm LSR}$=300 km s^{-1}.

Figure 10l.. O VI column density for 3 sightlines (and 25 significant non-detections), integrated from $v_{\rm LSR}$=300 to $v_{\rm LSR}$=500 km s^{-1}.

Figure 11.. Map of the deviation velocities of the H I high-velocity gas. Data from Hulsbosch & Wakker (1988) and Morras et al. (2000). The deviation velocity is the difference between the observed LSR velocity and the maximum velocity that can be easily understood in a simple model of Galactic differential rotation ($\rm v_{rot,\odot}$=220 km s^{-1}, $\rm R_\odot$=8.5 kpc, $\rm R_{MW}$=26 kpc, $\rm z_{ISM}$=2 kpc at $\rm R_\odot$, increasing to 6 kpc $\rm R_{MW}$, see Wakker 1991). The names of the major complexes are indicated. Contour levels are at 0.05, 0.5 and 1 K brightness temperature, or $\sim$2, 20 and 40$\times$10^{18} cm^{-2}.